COMPARATIVE STUDY ON EXTERNAL SELF CURING CONCRETE AND CONVENTIONAL CURING CONCRETE USING DIFFERENT BINDING MATERIALS (OPC AND PPC)

Thesis

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF TECHNOLOGY

in

CONSTRUCTION TECHNOLOGY AND MANAGEMENT

by

NGIRABAKUNZI CLAVER

(172 CM 029)

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

KARNATAKASURATHKAL, MANGALORE-575025

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May, 2019

DECLARATION

By the P.G (M.Tech) Student

I hereby *declare* that the P.G. Project Work Report entitled **"Comparative study on external self-curing and conventional curing concrete using different binding materials (OPC and PPC)"** which is being submitted to **National Institute of Technology Karnataka, Surathkal,** for the partial fulfillment of the requirement for the award of degree of **Master of Technology** in **Construction Technology and Management** in the **Department of Civil Engineering**, is a *bonafide report of the work carried out by me*. The material contained in this report has not been submitted to any university or Institution for the award of any degree.

....

NGIRABAKUNZI Claver (172 CM 029)

Department of Civil Engineering

Place: NITK, SURATHKAL

Date: May, 2019

CERTIFICATE

This is to *certify* that the P.G. Project Work Report entitled **"Comparative study on external self-curing and conventional curing concrete using different binding materials (OPC and PPC)"** submitted by **Mr.NGIRABAKUNZI Claver (172 CM 029),** as the record of the work carried out by him, is accepted as the P.G. Project Work Report submission in partial fulfillment of the requirements for the award of the degree of **MASTER OF TECHNOLOGY** in **CONSTRUCTION TECHNOLOGY AND MANAGEMENT** in the **Department of CIVIL ENGINEERING, N.I.T.K, Surathkal** during the year 2018-2019, is a bonafide work carried out by him under my supervision and guidance.

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NATIONAL INSTITUTE OF TECHNOLOGY KARNATAKA, SURATHKAL
DEPT. OF CIVIL ENGG.

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ABSTRACT

Concrete is the most widely used construction material due to its good compressive strength and durability. The imagination of a world without concrete is impossible as the concrete is a soul of infrastructures. Conventional concrete which is the mixture of cement, fine aggregate, coarse aggregate and water, needs curing to achieve strength. So it is required to cure for a minimum period of 28 days for good hydration and to achieve target strength. Lack of proper curing can badly affect the strength properties and durability of concrete. The strength and durability of concrete depends on the curing process of concrete. The ACI-308 Code states that "self-curing (external self-curing and internal self curing) refers to the hydration process of cement with water." The extent to which this reaction is completed influences the strength and durability of the concrete. Curing is the maintenance of a satisfactory moisture content and temperature in concrete for a period of time immediately following placing and finishing so that the desired properties may develop.Self-curing concrete is one type of modern concrete which cure itself by retaining its moisture content in it. The need for adequate curing of concrete cannot be overemphasized as it has a strong influence on the properties of hardened concrete. This study is investigating whether the use of self-curing concrete is economical for concrete compared to normal curing concrete in remote areas or other regions where there is scarcity of water without compromising the strength properties of concrete while using different binding materials (OPC and PPC). In the present study, comparison of compressive strength, tensile strength and flexural strength of concrete and concrete water absorption for normal and external self curing concrete have been made; concure WB concrete curing compound has been used for external self curing concrete. Experimental results indicated that conventional curing concrete for both binding materials (OPC and PPC mixes) has better mechanical properties and percentage concrete water absorption as compared to external self curing concrete.

Key words: Normal Curing concrete (NCC), External Self-Curing concrete (SCC), Self-curing agents, Concrete strength characteristics, workability and concure WB.

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CHAPTER 01

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Construction industry is growing day by day even in remote areas and desert regions. Even India and other countries are facing lot of problems in supplying drinking water to their citizens. Hence construction industries are under pressure in finding out alternative curing methods of curing concrete**.** Curing of concrete is maintaining of satisfactory moisture content in concrete during its early stages in order to develop the desired properties of concrete. Concrete is the most commonly used construction material in the world. It is basically composed of two components which are paste and aggregates controlled by workability of fresh concrete, durability and strength requirements based on concrete curing process (Chikmagalur 2010).

Proper curing is necessary to achieve desired strength and performance of concrete. In conventional concrete, curing is done after various stages like mixing, placing and finishing. Self-Curing is a technique which is used to provide proper moisture contents in concrete for better hydration for a long time,and then it can be used to provide additional moistureinconcretefor moreeffective hydration of cementand reducedself-desiccation. Self-Curing agent works to reduce self-desiccation contents present in the concrete and improves performance, strength and durability requirements. In conventional curing this is achieved by external curing applied after mixing, placing and finishing(Sujay Raghavendra N 2010). Concrete needs congenial atmosphere by providing moisture for a minimum period of 28 days for good hydration and to attain desired strength. Any laxity in curing will badly affect the strength and durability of concrete. Self-curing concrete is one of the special concretes in mitigating insufficient curing due to human negligence paucity of water in arid areas, inaccessibility of structures in difficult terrains and in areas where the presence of fluorides in water will badly affect the characteristics of concrete.(Jayeshkumar R. Pitroda 2014).

The need for adequate curing of concrete cannot be overemphasized because curing has a strong influence on the properties of hardened concrete, proper curing will increase durability, strength, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing effect. Curing may be achieved in a number of ways and the most appropriate means of curing may be dictated by the site or the construction method by spraying while the concrete is wet. Self-curing is a technique used by construction industry that use lot of water inthenameof curing to provide or promote indoor and outdoor construction activities in areas where there is scarcity of water. Self-curing concrete is the one which can meet the present and future requirements of concrete curing. As result of successful,recent tests and researches have recently put external self-curing in the forefront of breakthroughs of ideas of how to make better concrete (R. Sundharam 2016).

In case of columns and beams the application is done after the removal of formwork. On the horizontal surface, the curing compound is applied upon the complete disappearance of all bleeding water. It is Suitable for all general concreting applications and gives particular benefit for large area concrete surfaces and tunnel lining works. The days are not so far that all the construction industry has to switch over to an alternative curing system, not only to save water for the sustainable development of the environment but also to promote indoor and outdoor construction activities even in remote areas where there is scarcity of water (Akanksha A. Patil 2014). Considering the importance of alternative curing system to minimize usage ofwater and to increase concrete strength properties, this study focuses on external self-curing concrete technique. Previous studies [such as (R. Sundharam 2016),(Sujay Raghavendra N 2010),(Jayeshkumar R. Pitroda 2014) , (Chikmagalur 2010), (Akanksha Anantrao 2014)]conducted have analyzed compressive and tensile strengths between conventional curing and external self-curing concrete techniques. In this particular present study, concure WB is used as a curing compound for external self-curing concrete. In addition, flexural strength, water absorption for conventional and external self-curing concrete for both OPC and PPC, have discussed in this research project work.

1.2 OBJECTIVES OF THE STUDY

1.2.1 Main objective

General objective of this study is to establish a correlation and comparison of concrete strength by external self curing and conventional curing concrete in which equivalent curing methods for concrete specimens can accurately represent the curing conditions of concrete and also to reduce quantity of water required for concrete curing.

1.2.2 Specific objectives

The following objectives were determined for both OPC and PPC mixes to determine and compare the concrete strength properties while using different binding materials.

1. To study compressive, tensile and flexural strength of normal and external self curing concrete for OPC mix.
2. To study compressive, tensile and flexural strength of normal and external self curing concrete for PPC mix.
3. To compare the strength characteristics for normal and external self curing concrete between OPC and PPC mixes.
4. To determine concrete water absorption for normal and external self curing concrete between both OPC and PPC mixes in terms of concrete durability.

1.3 METHODOLOGY

In this experimental work, the methodology conducted for this research work was determined and discussed. This investigation was carried out to study the behavior of normal and external self-cured concrete within their ingredient materials. The followings are the methodologies adopted to achieve the objectives of this research project.

1. To conduct comprehensive literature review related to subject of self curing and normal curing concrete.
2. Selection of suitable ingredient materials required for concrete production including cement, aggregates, water and concrete curing compound to be applied on finished concrete surface.
3. Determine the relative quantities of these materials in order to produce concrete mix design.

4. Casting of concrete specimens and curing process by conventional curing and external self curing (by the application of curing compound on concrete surfaces) for both OPC and PPC mixes.
5. Performing physical and mechanical laboratory tests on external self curing and normal curing concrete.
6. To compare concrete strength behaviours for both conventional and external self curingbetween OPC and PPC mixes.
7. Determine the percentage concrete water absorption between OPC and PPC mixes for conventional curing and external self curing

1.4 SCOPE OF THE WORK:

The undertaken work program is summarized below:

1.4.1 Characteristics of Materials used in concrete production.

In order to assess the characteristics of the various ingredients of concrete, the following tests shown in table below are considered.

Table1.1Characteristics of materials used in concrete production

S.No	Materials	Laboratory tests
1.	Cement (OPC and PPC)	Specific Gravity, fineness, Normal Consistency and initial and final Setting time.
2.	Fine aggregates	Specific gravity, Sieve analysis,Fineness modulus, Water absorption and Moisture content.
3.	Coarse aggregates	Specific gravity, Sieve analysis, Fineness modulus, Water absorption and Moisture content.

1.4.2 Characteristics of Concrete Curing Compound material

The properties to decide the quality of concrete curing compound to be used are the following namely:

- Water retention
- Reflectance
- Drying period
- Long term setting and Non-volatile matter
- Concrete strength development

Table1.2Properties of concure WB curing compound

Fosrocconcure WB white (water based curing compound)	
Curing efficiency	Concure WB curing agent complies with the internationally recognized ASTM C309-90standard
Specific gravity	1 to 1.01 g/cc
Colour	Bulk liquid White
Covers	3.5 to 5.0 m^2/litre
Shelf life	12 months

1.4.3 Characteristics of Fresh concrete

In order to assess the characteristics of fresh concrete, the following aspects are considered:

- Mix design
- Workability

1.4.4 Characteristics of Hardened concrete

The following tests are carried out to establish the engineering properties between external self curing concrete and conventional/normal curing concrete:

- Compressive strength
- Split tensile strength.
- Flexural strength.
- Concrete water absorption

1.5 THESIS STRUCTURE:

This thesis consists of five chapters arranged carefully in the order to make it clear and understandable. This section represents a brief description of these chapters.

Chapter 01-Introduction: This chapter represents general introduction to self curing/external self curing concrete and conventional curing concrete, objectives of the research, scope of the work and methodology adopted in the research are included.

Chapter 02-Literature review: Provides a general review of relevant previous research related to self curing/external self curing and normal curing concrete and the main constituent materials.

Chapter 03- Materials and Methods: It describes the properties of the materials used in the test specimens, the size and the number of specimens, testing methods and the associated instrumentation to evaluate the characteristics and properties for external self curing and normal curing concrete. It outlines the types of laboratory tests, standards procedures adopted, materials properties and curing condition.

Chapter 04- Results and Discussion: This chapter describes the analysis of the results, the related discussion and observation from the testing has been included in a sequential manner. Result and discussion of the tests have been presented briefly.

Chapter 05-Conclusion: The significant conclusions obtained from experimental investigations of this study have been integrated and presented in a logical sequence. At the end, references used in this research are presented.

CHAPTER 02

LITERATURE REVIEW

2.1 HISTORICAL DEVELOPMENTOF CURING AND SELF-CURING CONCRETE

2.1.1 Curing of concrete

Curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration. It may be either after it has been placed in position (or during the manufacture of concrete products), thereby providing time for the hydration of the cement to occur. Since the hydration of cement does take time days and even weeks rather than hours, cuing must be under taken for a reasonable period of time. If the concrete is to achieve its potential strength and durability curing may also encompass the control of temperature since this affects the rate at which cement hydrates.Curing can be described as keeping the concrete moist and warm enough so that the hydration of cement can continue. More elaborately, it can be described as the process of maintaining satisfactory moisture content and a favorable temperature in concrete during the period immediately following placement, so that hydration of cement may continue until the desired properties are developedto a sufficient degree to meet the requirement of service(Sujay Raghavendra N 2010).

As per ACI-308R

The term "curing" is frequently used to describe the process by which hydraulic-cement concrete matures and develops hardened properties over time as a result of the continued hydration of the cement in the presence of sufficient water and heat.

- **As per IS:456-2000**

“Curing is the process of preventing the loss of moisture from the concrete.”Curing is the maintenance of a satisfactory moisture content and temperature in concrete for a period of time immediately following placing and finishing so that the desired properties may develop.

Curing has a strong influence on the properties of hardened concrete; proper curing will increase durability, strength, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing etc.

2.1.2 Duration of curing

The time to start curing of concrete depends on the evaporation rate of moisture from the concrete. The evaporation rate is influenced by wind, radiant energy from sunshine, concrete temperature, climatic conditions, relative humidity. The evaporation of moisture is driven by the difference in vapor pressure on concrete surface and the in surrounding air. When the difference is high, evaporation rate is high.The curing period may depend on the properties required of the concrete, the purpose for which it is to be used, and the ambient condition, ie the temperature and relative humidity of the surrounding atmosphere. Curing may be applied in a number of ways and the most appropriate means of curing many be dictated by the site or the construction method(Chikmagalur 2010).

Concrete should not be allowed to dry fast in any situation. This condition should be maintained for 24 hours. Best way is to keep the concrete under wet gunny bags for 24 hours and then commence water by way of ponding or spraying. The curing period varies for different structures, situations, different atmospheric conditions; type of cement and grade used and mix proportion. In general, concrete must be cured at least for seven days if ordinary Portland cement is used. If rapid hardening cement is used, the period can be reduced slightly. If low heat cement is used curing can be extended to 21 days. In cold weather regions, curing should be continued for a long time (R. Sundharam 2016).

2.1.3 Evaporation of water from concrete freshly placed on site

The graph below shows the effects of air temperature, humidity, concrete temperature, and wind velocity together on the rate of evaporation of water from freshly placed and unprotected concrete(Based on ACI:305 R-5).

To use this chart helps determining the rate of evaporation of water from freshly placed and unprotected concrete:

i. Enter with air temperature and move up to relative humidity
ii. Move right to concrete temperature
iii. Move down to wind velocity and
iv. Move left to read rate of evaporation.

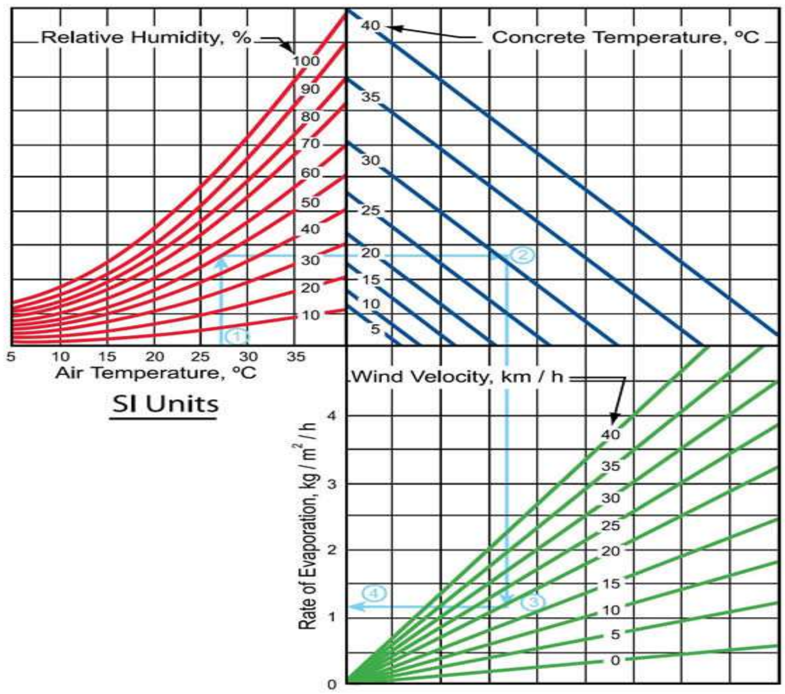
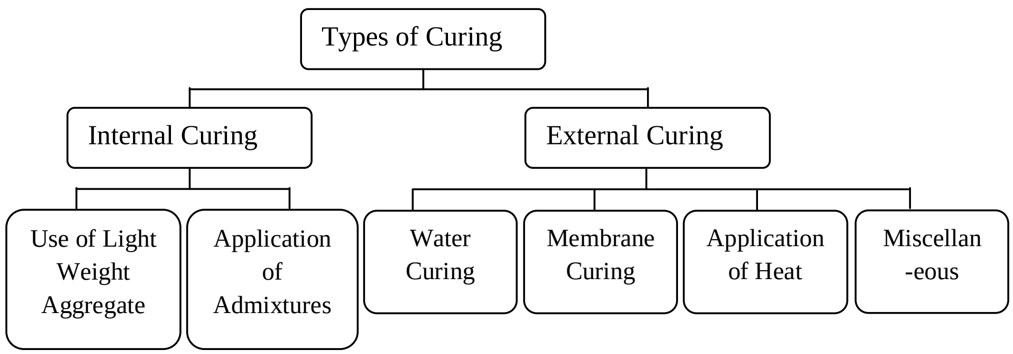


Figure 2.1 Evaporation rate of water from concrete

- With air temperature at 25°C
- Withrelativehumidityat40%
  With concrete temperature at 25°C
- With a wind velocity of 20 km/hr the rate of evaporation would be 1.1 kg/m² hr. The highlighted line plots the example described above.
- The nomogramcan be used for calculation of evaporation rates if other variables are known (a nomogram, alignment chart or abaques, is a graphical calculating device, a two-dimensional diagram designed to allow the approximate graphical computation of a mathematical function).

To determine the evaporation rate from the graph enter the graph at the air temperature (in this case 25°C) and move vertically to intersect the curve for relative humidity encountered - here 40%. From this point move horizontally to the respective line for concrete temperature - here 25°C. Move vertically down to the respective wind velocity curve and then horizontally to the left to intersect the scale for rate of evaporation. Trouble with plastic cracking is potentially in the making when the rate of evaporation exceeds 0.5 kg/m² hr. When the evaporation rate exceeds 1.0 kg/ m² hr precautionary measures to prevent plastic shrinkage are almost mandatory.

2.1.4 Types and methods of concrete curing



2.1.4.1 External curing

- Water curing:Immersion, ponding, spraying and wet covering
- Steam curing
- Self-curing concrete/ membrane curing and
- Miscellaneous

a) Water curing

i) Ponding and Immersion

On flat surfaces, such as pavements and floors, concrete can be cured by ponding. Earth or sand dikes around the perimeter of the concrete surface can retain a pond of water. Ponding is an ideal method for preventing loss of moisture from the concrete; it is also effective for maintaining a uniform temperature in the concrete. The curing water should not be more than about 11°C (20°F) cooler than the concrete to prevent thermal stresses that could result in cracking.The most thorough method of curing

with water consists of total immersion of the finished concrete element.
This method is commonly used in the laboratory for curing concrete test specimens(Sujay Raghavendra N 2010).

- **Ponding method**: Is suitable for large slab and for road pavements. On top of the slab, small ponds are prepared from clayey soil, and water is stored up to a depth of 50mm for 28 days. Water used in ponding should be of good or potable quality (water fit for drinking).

- **Immersion:** The precast members are immersed in curing tank for a certain period. Immersion in water is particularly important when the concrete has a low water-cement ratio.

Figure 2.2 Ponding and immersion water curing

ii) Spraying water

This is the simplest method for curing. In this method, after removal of shuttering or the framework/form work, water is sprayed on the concrete surface through a hose or by bucket, a number of times during each day. This method is suitable for small works. It requires great care in supervision, and as soon as the concrete dries, water has to be sprayed(Chikmagalur 2010).

Figure 2.3 Spraying water curing

iii) Wet Coverings

Fabric coverings saturated with water, such as burlap, cotton mats, rugs, or other moisture-retaining fabrics, are commonly used for curing.Treated burlaps that reflect light and are resistant to rot and fire are available.The requirements for burlap are described in the Specification for Burlap Cloths Made from Jute or Kenaf(AASHTO M182), and those for white burlap-polyethylene sheeting aredescribed in ASTM C 171 (AASHTO M 171).

Figure 2.4 Wet Coverings

b) Steam Curing

Steam curing is advantageous where early strength gain in concrete is important or where additional heat is required to accomplish hydration, as in cold weather. Steam curing is used for pre-cast concrete products.Due to steam, the components are heated uniformly and the strength is gained at a very fast rate.

Steam can pass and penetrate through small gaps of stacked pre-cast concrete products and strength is achieved evenly from all sides(Chikmagalur 2010).

Steam curing can be done in two ways:

- Low steam pressure (for enclosed cast-in-place structures and large precast concrete units) and
- High-pressure steam in autoclaves (for small manufactured units).

➢ **Low pressure steam curing:** In this method the steam curing is done at atmospheric pressure and about 70% of the 28-days strength can be achieved in 16-24 hours.

➢ **High pressure steam curing:** In this method steam curing is done at a pressure of 8 atmospheres that is 800KN/m^2.

Main disadvantage in fast curing is that rapid rise of temperature cause loss of strength. This difficulty is minimised with application of high pressure. High pressure steam curing gives high durability to concrete.A typical steam-curing cycle consists of an initial delay prior to steaming, a period for increasing the temperature, a period for holding the maximum temperature constant, and a period for decreasing the temperature. Steam curing at atmospheric pressure is generally done in an enclosure to minimize moisture and heat losses(Jayeshkumar R. Pitroda 2014).

Application of steam to the enclosure should be delayed until initial set occurs or delayed at least 3 hours after final placement of concrete to allow for some hardening of the concrete. However, a 3- to 5- hour delay period prior to steaming will achieve maximum early strength. Steam temperature in the enclosure should be kept at about 60°C (140°F) until the desired concrete strength has developed. Strength will not increase significantly if the maximum steam temperature is raised from 60°C to 70°C (140°F to 160°F). Steam-curing temperatures above 70°C (160°F) should be avoided.(M. POOVIZHISEL 2017)**.**

Typical cycle of steam curing consists of the following phases:

- An initial delay prior to steaming
- A phase for increasing the temperature
- A phase for holding the maximum temperature constant
- A phase for decreasing temperature

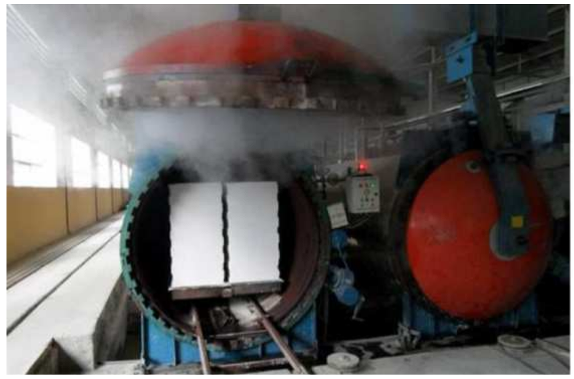


Figure 2.5 Steam Curing

c) Miscellaneous Curing

Calcium chloride is used either as a surface coating or as an admixture. It has been used satisfactorily as a curing medium. This method is based on the fact that calcium chloride being a salt shows affinity for moisture. The salt not only absorbs moisture from atmosphere but also retains it at the surface. This moisture held at the surface prevents the mixing water from evaporation and thereby keeps the concrete wet for a long time to promote hydration. Formwork prevents escaping of moisture from the concrete, particularly, in the case of beams and columns. Keeping the formwork intact and sealing the joint with wax or any other sealing compound prevents the evaporation of moisture from the concrete. This procedure of promoting hydration can be considered as one of the miscellaneous methods of curing.(Jayeshkumar R. Pitroda 2014).

2.1.5 Self-curing concrete (S.C.C)

As per IS:456-2000 “Curing is the process of preventing the loss of moisture from the concrete”. Self-curing concrete is the one which can cure itself by retaining its moisture content. A concrete can be made to self cure by adding curing admixtures or by the application of curing compounds.Sometimes works are carried out in place where there is acute shortage of water and the application of water curing is not possible for reasons of economy.

Prevention of moisture loss from the surface of flat concrete works such as highways and airports have been challenging task for construction managers.If the evaporation of moisture from concrete is not prevented properly, it may results in plastic shrinkage cracks, poorly formed hydrated products, finishing problems and other surface defects. Sometimes concrete is placed in some inaccessible, difficult or far places, where curing cannot be properly done or supervised(Chikmagalur 2010).

2.1.5.1 Self-curing concrete by adding admixtures

Various admixtures used are conplast NC, conplast CN and conplast S D 110, concure WB, etc. Rheo cure is the curing admixture used in U K for plane concreting. The admixtures used for curing concrete with certain chloride which will lead to corrosion of reinforcement, its use is restricted only within plain concrete.

2.1.5.2 Self-curing concrete by the application curing compounds

Curing compounds available are wax based, water based, and resin based. The curing compound applied on concrete acts as a protective layer and sealed the moisture content within the concrete. The curing compounds available are concure WB, Concurelp 90, etc**.**

2.1.5.3 Mechanism of self-curing concrete

The mechanism of self-curing can be explained as follows:continuous evaporation of moisture takes place from an exposed surface due to the difference in chemical potentials (free energy) between the vapour and liquid phases. The polymers added in the mix mainly form hydrogen bonds with water molecules and reduce the chemical potential of the molecules, which in turn reduces the vapour pressure, thus reducing the rate of evaporation from the surface.Self-cure concrete contains a chemical agent that reduces the evaporation of water from its surface, primarily by reducing the vapour pressure at the concrete pore solution surface. The self-curing agent developed at the Concrete Technology Unit also produces an alteration in cement hydration product microstructure, and it was considered that this might also contribute to the improved water retention properties(Abishek 2016).

To investigate the mechanism of self-curing, weight loss measurements were conducted on both self-cure and ordinary pastes exposed to controlled ambient conditions, whilst thermo gravimetric analysis was carried out on identical specimens. It was found that, whilst the evolution of heat of hydration renders the early stages of drying very complex, it was possible to examine the diffusion dependent stage of drying**.** The diffusion coefficients observed for water vapour passing through the dry region of the self-cure paste surface were much lower than those observed for the control. This has been attributed to two mechanisms: the lower vapour pressure above the pore solution leading to a smaller difference across the dried portion of the paste and lower relative humidity in the cement pores, and the change in microstructure which reduces permeability.The compound molecules are primarily hydrophobic in nature with hydrophilic terminal group. Hydrophilic terminal group attaches itself to the film of bleeding water. While the long hydrophobic chain maintains a vertical orientation away from the bleeding water, water molecules do not possess sufficient energy to escape through the hydrophobic layer, which results in a quick reduction in the evaporation loss**.** The hydrophobic effect represents the tendency of water to exclude non-polar molecules; the effect originates from the disruption of highly dynamic hydrogen bonds between molecules of the liquid.

A hydrophilic molecule or portion of a molecule is one that has a tendency to interact with or be dissolved by water. A pure hydrocarbon molecule is incapable of forming hydrogen bonds with water. The hydrogen bonds are partially reconstructed by building a water "cage" around the compound molecule, the water molecules that form the "cage" have substantially restricted mobilities(Ravikumar 2015).

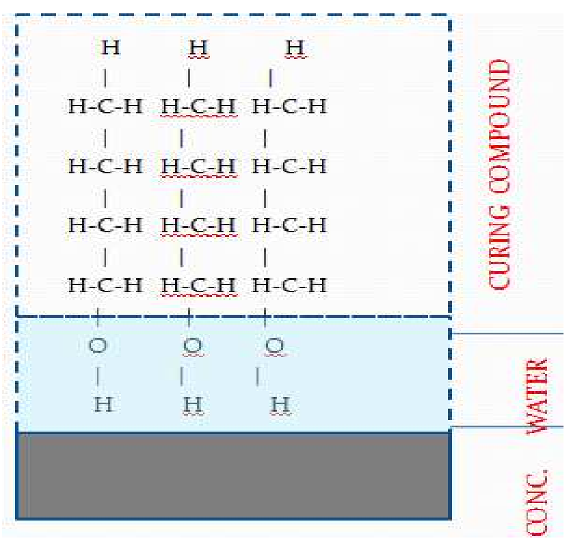


Figure 2.6 Self-curing concrete mechanism

2.1.5.4 Durability of self-cured concrete

Venkateswarlu et al.(2015), reported results of several durability tests conducted on Conventional Concrete with PEG-600 asaself-curing compound for concrete specimens. It was found that initial surface absorption, chloride ingress, carbonation, corrosion potential, and freeze/thaw resistance characteristics were all the better in air cured self-cure concrete than in the air cured control concrete. This improvement appears to be dependent on the admixture dosage. It is possible to achieve durability properties with higher quantities of the self-curing chemical/compound.Concrete that is capable of retaining greater quantities of water, ordinary concrete when cured in the air has been developed by means of an addition of a self-cure chemical (SCC) which was a water-soluble polymeric glycol identified as the chemical(self-curing compound Polyethylene glycol (PEG)). The water retention leads to a greater degree of cement hydration and hence improved properties of concrete in comparison to control test specimens. The features of self-cure concrete provide good durability properties for concrete(Venkateswarlu et al 2015).

2.1.6 Methods used in self-curing concrete

Currently, there are two major methods available for self-curing of concrete. The first method uses saturated porous lightweight aggregate,super-absorbent Polymers and shrinkage reducing admixture (internal self-curing) in order to supply an internal source of water, which can replace the water consumed by chemical shrinkage during cement hydration. The second method uses curing compounds applied to the concrete surface (external self-curing) which reduces the evaporation of water from the surface of concrete and also helps in water retention(Chikmagalur 2010).

The major methods available for self-curing concrete are the following:

- External self-curing of concrete
- Internal self-curing of concrete

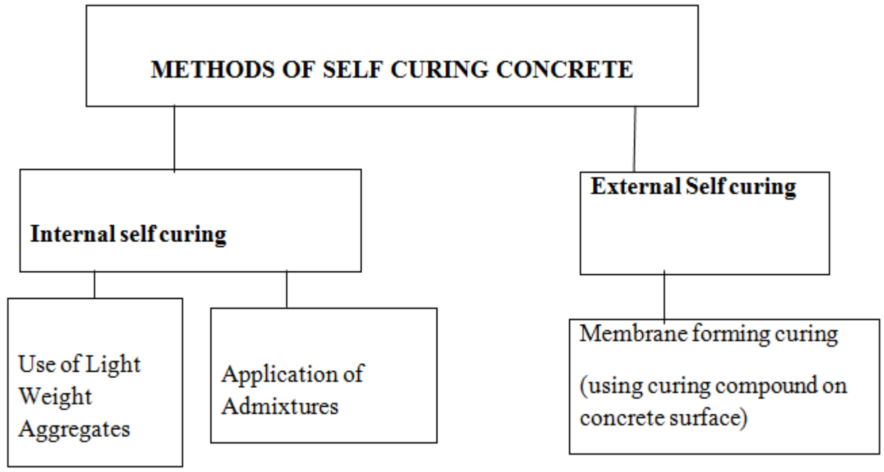


Figure 2.7 Methods of self-curing concrete

2.1.6Internal self-curing (IC) of concrete

The ACI-308 Code states that "internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing water." Conventionally, curing concrete means creating conditions such that water is not lost from the surface i.e., curing is taken to happen 'from the outside to inside'. In contrast, 'internal curing' is allowing for curing from the inside to outside' through the internal reservoirs (in the form of saturated lightweight fine aggregates, superabsorbent polymers, or saturated wood fibers) Created. 'Internal curing' is often also referred to as 'Self–curing'(Jayeshkumar R. Pitroda 2014).

Internal curing refers to methods of providing moisture from within the concrete as opposed to outside the concrete. This water should not affect the initial water to cement ratio of the fresh concrete. Lightweight (low-density) fine aggregate or absorbent polymer particles with an ability to retain a significant amount of water may provide additional moisture for concretes prone to self-desiccation. When more complete hydration is needed for concretes with low water to cement ratios (around 0.30 or less), 60 kg/m^3 to 180 kg/m^3 (100 lb/yd^3 to 300 lb/yd^3) of saturated lightweight fine aggregate can provide additional moisture to extend hydration, resulting in increased strength and durability (Ram Lohar1 2016)**.**

For many years, we have cured concrete from the outside in; internal curing is for curing concrete from the inside out. Internal water is generally supplied via internal reservoirs, such as saturated lightweight aggregates (LWA), superabsorbent polymers (SAPs- think baby diapers), saturated wood fibers, or saturated crushed (returned) concrete aggregates (CCA).All of the fine aggregate in a mixture can be replaced with saturated lightweight fine aggregate to maximize internal moist curing. Internal moist curing must be accompanied by external curing methods.Any negligence in curing will interfere in the strength and durability of concrete. Shrinkage reducing agents and lightweight aggregates such as Polyethylene-glycol and Leca, Silica fume and stone chips are used respectively to achieve effective curing results(Jagannadha Kumar 2012).

2.1.6.1 Mechanism of Internal Curing

Continuous evaporation of moisture takes place from an exposed surface due to the difference in chemical potentials(free energy) between the vapour and liquid phases. The polymers added in the mix mainly form hydrogen bonds with water molecules and reduce the chemical potential of the molecules which in turn reduces the vapour pressure, thus reducing the rate of evaporation from surface(Jagannadha Kumar 2012).

To understand the mechanism of Internal Curing(IC), the water involved in it needs to be sub divided into following heads: The volume of water available for IC, (Absorption capacity of the agent) , the ability of the water to leave the LWA when needed for IC(desorption ability of agent), and the effect of particle size, content and distribution of the LWA in the matrix for better dispersion of IC water in the paste (Nishant Yadav2013).

2.1.6.2 Distribution of Internal water Reservoirs for Curing

The transport distance of water within the concrete is limited by percolation of the capillary pores in low w/c ratio pastes. With water-reservoirs well distributed within the matrix, shorter distances have to be covered by the curing water and the efficiency of the internal-curing process is consequently improved.

The concept of internal curing was established, based on dispersion of very small, saturated lightweight aggregate (LWA) throughout the concrete, which serve as tiny reservoirs with sufficient water to compensate for self-desiccation. The spacing between the LWA particles is conveniently small so that the water travels smaller distances to counteract self-desiccation. The amount of water in the LWA can therefore be minimized, thus economizing on the content of the LWA(Jayeshkumar R. Pitroda 2014).

2.1.6.3 Potential material for internal self-curing concrete

The following materials can provide internal water retention:

- Lightweight Aggregate (natural and synthetic, expanded shale)
- Super-absorbent Polymers (60-300 nm size)
- Shrinkage Reducing Admixture (propylene, glycol type i.e. Polyethylene-glycol)
- Lightweight fine aggregates 19mm Coarse (Water absorption: 20%) and Wood powder

2.1.6.4 Advantages of Internal self-curing concrete

- It is the alternate of construction in desert regions where major scarcity of water is there.
- Self-Curing (Internal Curing) is a method to provide the water to hydrate all the cement, accomplishing what the mixing water alone cannot do.
- Provides water to keep the relative humidity (RH) high, keeping self-desiccation from occurring.
- Eliminates largely autogenous shrinkage and can make up for some of the deficiencies of external curing, both human related (the critical period when curing is required in the first 12 to 72 hours) and hydration.
- Increases the strength of concrete to some extent.

2.1.7 External self-curing

External self-curing concrete is the one which can cure itself by retaining its moisture content within the concrete after the application of curing compound on the concrete surface.

Concrete can be made to self-cure by the application of curing compounds on the surface of the concrete. The curing compound is applied by means of brushing or spraying(Sujay Raghavendra N 2010).

2.1.7.1 Applications of external self-curing concrete

A spray applied the membrane to retain moisture in concrete for effective curing is suitable for all general concreting applications and of particular benefit for large area concrete surfaces, such as airport runways, roads and bridge works. It is also suitable for piece works where it is difficult to curing and for tunnel lining work;thecompound is used in piece work to prevent concrete surfaces defects where it is difficult to carry out normal curing works**.**Whenthe concrete surface has dried, the surface should be sprayed with water and made fully damp before curing compound is applied. In the case of columns and beams, the application is made after the removal of formwork and it is applied by brush or by spraying while the concrete is wet(Sujay Raghavendra N 2010).

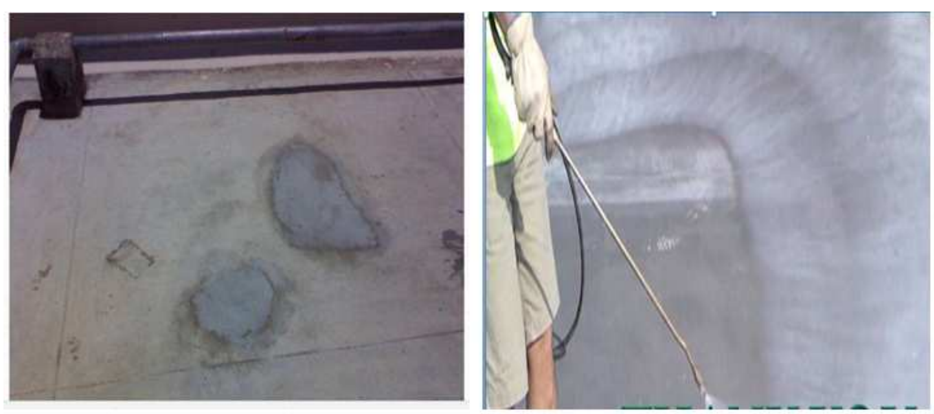


Figure 2.8 Application of external self-curing concrete

2.1.7.2 Advantages of external self-curing concrete

- Improved curing of concrete enhances cement hydration and provides a more durable concrete.
- Control of moisture loss improves surface quality, reducing permeability, producing a hard wearing; dust free Surface and minimizing the potential for surface cracking and shrinkage.
- Fugitive colour provides a visual guide during application.
- Water based, therefore, non-flammable.
- Spray application reduces labour costs and eliminates the need for alternative curing systems.
- Lower maintenance.
- Increases early age strength

2.1.8 Concrete curing compound used for external self-curing concrete

Concrete curing compound is a compound which helps to prevent the loss of moisture content from the concrete. So, concrete is properly cured which results in the full development of concrete strength as perASTM C309-90.

2.1.8.1 Types of Concrete Curing Compounds

- **Synthetic Resin Concrete Curing Compound:** Synthetic resins will seal the concrete by forming membrane. If we want to provide plastering, the membrane can be removed by washing it with hot water.
- **Acrylic Concrete Curing Compound**: Acrylic is made of polymers of acrylic acid. It also seals the concrete in good manner. It is having property of adhesion to the subsequent plaster. No need to wash the surface of acrylic with hot water if we want to provide plastering.
- **Wax Concrete Curing Compound:** Wax compound have similar properties like resin compound. The wax membrane will lose its efficiency with time increment.
- **Chlorinated Rubber Curing compound:** Chlorinated rubber type curing compound will form thick layer when we applied.

- It seals the concrete tightly and also fills the minute pores present in the concrete. But the film cannot stay for longer period. It is wear out in the long run(Chikmagalur 2010)**.**

2.1.8.2 Properties of Concrete Curing Compound

There are 5 properties to deicide the quality of concrete curing compound namely(as per AASHTO T 155):Water retention, reflectance, drying period, long term setting and non-volatile matte.

Testing of concrete curing compounds can be carried out (as per ASTM C 309). ASTM C 309 provides specifications and testing of concrete curing compounds.

2.1.8.3 Uses of external self-curing Compound

Membranes forming curing compounds are used to retard the loss of water from concrete during the early age. They are used not only for curing fresh concrete but also further curing after removal of formwork. Application of these compounds seals the concrete surface effectively by forming monomolecular film on the surface. Membrane forming curing compounds is a long chain of hydrocarbon molecules. This forms monomolecular film on the surface of the concrete immediately after placing (as perASTM C 1315). White-pigmented concrete curing compounds are wax-based dispersions with selected white pigments. When properly applied, which optimizes water retention.

The white pigment reflects the sun's rays and helps to keep the concrete surface cooler and prevent excessive heat buildup. It is ideal for application on exterior, horizontal surfaces, such as highways, airports pavements.The curing compound is applied by brush or by spraying while the concrete is wet. In case of columns and beams the application is done after the removal of formwork. On the horizontal surface, the curing compound is applied upon the complete disappearance of all bleeding water. It is Suitable for all general concreting applications and gives particular benefit for large area concrete surfaces, such as airport runways, roads and bridgeworks. It is also suitable for piece works where it is difficult to curing and also suitable for tunnel lining work.

These curing compounds possess waxes, natural resins, synthetic resins and solvents of high volatility.Generally white or gray colors appear when we apply to cure compound on fresh concrete. These pigments are provided heat reflectance and also useful to check the area of curing completed. Curing compound is applied when the finishing is completed and free water present on the surface gets disappeared. The curing compound is applied through brushing or spraying pipe with a constant rate of pressure(Sujay Raghavendra N 2010).

Generally, one liter of curing compound can be sprayed for 0.20 – 0.25m^2 surface area of fresh concrete. The sprayer pressure is usually 0.5 – 0.7 MPa. In small areas, we can also use brushes or paint rollers to apply curing compounds.
Curing compound should not be applied on surfaces which receive additional concreting(ASTM C 309).Curing compounds are applied on the fresh concrete surface to prevent moisture loss from the concrete after fresh concrete is properly placed, compacted and finished, so that concrete must have sufficient desired property of good concrete.

2.1.8.4 Advantages of Self-curing compounds

- When properly applied, provides a premium-grade film, which optimizes water retention.
- Protects by reflecting the sun's rays to keep the concrete surface cooler and prevent excessive heat buildup, which can cause thermal cracking.
- Furnished as a ready-to-use, true water-based compound. Produces hard dense concrete, minimizes hair checking, thermal cracking, dusting and other defects.
- Offers a compressive strength significantly greater than improperly or uncured concrete.
- Improves resistance to the abrasion and corrosive actions of salts and chemicals minimizes shrinkage.

2.1.8.5 Concure WB concrete curing compound

The curing compound used is “concure WB” which is a chemical product of fosrocConcure WB White. Concure WB is water based concrete curing compound based on a low viscosity wax emulsion. It is supplied as a white emulsion which forms a clear film on drying.When first applied to a fresh cementitious surface the emulsion breaks to form a continuous, non-penetrating white coating. This dries to form a continuous clear film which provides a barrier to moisture loss, ensuring more efficient cement hydration, improved durability and reduced shrinkage (Chikmagalur 2010).

- **Efficiency of concure WB curing compound**

Concure WB curing agent complies with the internationally recognisedASTM C309-90 standard. Specific gravity: 1 to 1.01 g/cc, Colour: Bulk liquid White Supplied in 200 litre drums. Covers 3.5 to 5.0 m2 /litre, Shelf life:12 months.

The curing compound “concure WB” is a product of fosrocchemicals.ConcureWBis water based concrete curing compound based on a low viscosity wax emulsion. It is supplied as a white emulsion which forms a clear film on drying. When applied to the surface of fresh cementitious concrete, the emulsion breaks to form a continuous, non-penetrating white coating that prevents the loss of moisture from the concrete surface(Sujay Raghavendra N 2010)**.**

- **Specifications of concure WB:** Base–wax, shelf life–12 months, coverage–3.5 to 5 m^2/litre and specific gravity-0.98 at 25°C.
- **Features:** Single application, no other curing necessary, easy and safe spray application and endures (continuous)hard wearing surface.

Figure2.9Concure WB curing compound

For health and safety Concure WB does not fall into the hazard classifications of current regulations, however, it should not be swallowed or allowed to come into contact with skin and eyes either in bulk or spray form.Suitable protective gloves and goggles should be worn. Splashes on the skin should be removed with water. In case of contact with eyes rinse immediately with plenty of water and seek medical advice(Chikmagalur 2010).

2.1.8.6 Application procedure of Concure WB Curing compound

The curing compound is applied by brush or by spraying while the concrete is wet. In case of columns and beams the application is made after the removal of formwork. On the horizontal surface, the curing compound is applied upon the complete disappearance of all bleeding water.After spraying, no further application of water or other material is necessary to ensure continued curing. The concrete surface should not be disturbed until it has sufficient strength to bear surface loads. The applied film should not be walked on before it is fully dry and care should be taken to ensure that the film is not broken.

In the case of road and pavements the curing compound is applied after texturing. In case the concrete surface has dried, the surface should be sprayed with water and thoroughly wetted and made fully damp before curing compound is applied. The container of the curing compound should be well stirred before use.The compound is sprayed on a surface in one even coat with a hand or power sprayer as soon as the surface water disappears from the concrete surface. It takes nearly 10 to 15 minutes for its drying and it forms a thin water proofing film on the surface. The application of this curing compoundis shown in fig below(Sujay Raghavendra N 2010).

Figure 2.10 Application of concrete curing compound

Precautions: Keep from freezing. Do not apply when the temperature of the air and/or the concrete is less than 40º F (4º C), do not mix or dilute with any other products or liquids, do not use on surfaces that are later to be painted, tiled, hardened, sealed or treated in any manner. Not recommended for use on residential applications and also it is applied in two coats. If needed more coat may be applied.

2.2 LITERATURE SURVEY

2.2.1 Strength characteristics between conventional and self-curing concrete

Chikmagalur (2010)studiedonexternalself-curing of concrete. The study investigated the performance of self-curing of concrete withConcure WB curing agent (specific gravity 0.98), its advantages and applications compared to conventional curing concrete. This investigation was carried out on 53 grades OPC to study the strength behaviour and other parameters of concrete prepared from above mentioned cement. The physical properties of cement(specific gravity of 2.85), fine aggregate(specific gravity of 2.50 and fineness modulus 2.85), coarse aggregate (specific gravity of 2.60 and fineness modulus of7.13)were determined in accordance with BIS specifications. On fresh concrete workability related tests suchas slump test, compaction factor test and on hardened concrete strength related testssuch as compressive strength test and split tensile strength test were conducted in accordance with BIS specifications. The grade of concrete chosen was M25 of w/c 0.55. The result of the investigation clearly indicated that self-curingconcrete is economically in places where there is shortage of water and in remote regions withoutcompromising the performance characteristics of concrete including durability. It was observed that the variation between concrete cured conventionally and with external self-curing compound was about 3.32% for compression strength and 20.94% for split tensile strength. Hence self-curing concrete is more economical because it eliminates the curing charges and efficiently adapted in the regions where scarcity of water is a big problem. Spray application reduces labor costs and eliminates the need for alternative curing systems**.**Self-curing concrete is the best solution to theproblems faced in the desert region and faced due tolack of proper curing.

Krishna Rao et al.(2010) studied the influence of curing on the strength of a standard grade concrete mix. The parameters of the study included the curing period (1, 3, 7, 14 and 28 day), curing method was conventional wet curing, membrane forming curing(withconcure WB curing compound complying with the internationally recognized ASTM C309-90)and accelerated curing. The types of cement used were ordinary Portland cement(43 grade OPC), Portland pozzolana cement(43 grade PPC) andordinary Portland cement(OPC) 43 grade +10% Silica fume(SF) replacement for cement. A total of 99 cubes specimens were cast and cured under different conditions before testing. Test results indicated a drop in strength at all ages for concretes with PPC and the one in which 10% OPC was replaced by Silica fume(SF) in comparison with the concrete with OPC. Curing by membrane forming curing compound yielded nearly the same results as that of conventional wet curing for concrete with OPC and there was a marginal decrement in concrete strength with PPC. Predicted 28-day strength of concrete from the accelerated curing test was found to be on a conservative side compared to control concrete.

Akanksha A. Patil(2014) investigated the Comparative study on compressive strength of Self cured Self-compacting concrete (SCC) and normally cured self-compacting concrete (SCC**).** This investigationwas done withself-curing material i.e. Materkure107i(elative density :1± 0.05 , colour : white liquid) and membrane forming concrete curing compound(Concure WB: specific gravity : 1 to 1.01 g/cc , colour : bulk liquid white , covers 3.5 to 5.0 m2/litre and shelf life–12 months). The other materials used were 53 grade OPC of specific gravity 3.15, fine aggregate having specific gravity 2.60 and fineness modulus 2.783, coarse aggregate having specific gravity of 2.9, silica fume having specific gravity 2.38, ordinary potable water andSuperplasticisersGLENIUM B233complies with IS: 9103– 1999 were used for this study. The study was investigating that weather the use of self-curing compound is economical or not in remote areas of water without compromising with the compressive strength of concrete. From the experimental results obtained, The following conclusions were achieved,Self-curing with curing compound Concure WB gives about 10% less compressive strength than normal water curing, also self-curing with curing compound materkure107i gives about 15% less compressive strength than normal water curing, in areas with shortage of water, sustainability of water can be achieved by using suitable chemical compounds for curing of concrete, compressive strength can also be achieved by using chemical compounds for curing and spray application reduces labor costs and eliminates the need for alternative curing systems.From each type of curing 3 days, 7 days, 28 days and 90 days compressive strength results were observed.

Mohammed Shafeeque et al. (2016)studied on thestrength comparison of self-curing concrete and Normal curing concrete. The aim of this investigation was to study the strength properties of concrete using water soluble Polyethylene Glycol as the self-curing agent. The function of the self-curing agent is to reduce the water evaporation from the concrete, and hence they increase the water retention capacity of concrete compared to the conventionally cured concrete. The use of self-curing admixtures is very important from the view point that saving of water is a necessity in everyday life (each one cubic meter of concrete requires $3m^3$ of water in construction, most of which is used for the curing). In this study, compressive strength and split tensile strength of concrete containing self-curing agent were investigated and compared with those of the conventionally cured concrete. An experimental program was carried out in different stages. First preliminary tests were conducted on fine aggregate having a specific gravity of 2.58and fineness modulus of 2.783 , coarse aggregate having a specific gravity of 2.81, cement (ordinary Portland Cement-Grade 53 having a specific gravity of 3.2) and Potable water were used . In the second stage of the project, the experimental program was designed to investigate the strength of self-curing concrete by adding polyethylene glycol PEG (600) at 0.5%, 1%, 1.5%, and 2% by weight of cement.From experimental results obtained, the following conclusion was taken; it was found that self-curing concrete has maximum workability at 1% application of PEG, as a percentage of PEG600 increased slump and flow values increased for both M20 and M25 grade of concrete. The optimum dosage of PEG600 for maximum strength (compressive and tensile) was found to be 1% for both M20 and M25 grade. Strength of self-curing concrete was equal to that of conventional curing concrete. Self-curing concrete is an alternative to conventional concrete in desert regions where scarcity of water is a major problem.

Radhakrishna and Rajasekhar (2015)have been studied an experimental investigation on self-cured concrete.The aim was to study thestrength of conventional curing concrete and self-cured concrete for compressive strength and tensile strength of similar mix design for 7 days and 28 days. The study was carried out on standard concrete cubes of dimensions 150mmx150mmx150mm in which the variation of internal moisture content was measure by weighing the cubes at regular intervals. The concrete cubes were exposed to the environment in which chloride was present to find out the durability of self-curing concrete and compressive strength of cubes are determinedto find the strength of concrete cubes. Thematerials used were sand having specific gravity 2.68 and fineness modulus 2.507 ,grade 53 Sri Chakra cement with of specific gravity 3.09 , coarse aggregates having the maximum size of 20 mm and Polyvinyl Alcohol (PVA) as a self-curingagenthas a melting point of 230*C and 180-190*C are described. The study has shown that the water retention for the concrete mixes incorporating self-curing agent is higher when compared to conventional concrete mixes, as found by the weight with time. When compared to conventional concrete, self-curing concrete resulted in better hydration with time under drying condition. The results also show that the cement content and the w/c ratio affect the performance of the self-curing agent. Compressive, tensile and flexural strength are higher when polyvinyl alcohol (0.48% by the weight of cement) is used as a self-curing agent.The authors concluded that when polyvinyl alcohol percentage increases, it results in a reduction of weight loss and the durability of self-curing concrete to sulphate salts and chloride induced corrosion and it is needed to be evaluated.

Manojkumar and Maruthachalam (2013)studiedan experimental investigation on Self-curing Concrete. The self-curing materials used are the use of super absorbent polymer (SAP) and the application of wax based membrane curing compound on the demoulded concrete specimens .The super absorbent polymer was used as a self-curing agent. The grade of concrete adopted for investigation was M40, based on the experimental investigation carried out. The materials used in this study were Portland pozzolona cement of 53 grades, fine aggregate (locally available river sand conforming to Indian standard (Zone-II), coarse aggregate (Locally available quarry stone in good strength passing through 20 mm and retain 10mm sieve, water (ordinary potable water without acidity and alkaniety available in the laboratory), super Plasticizer(Conplast SP 430) and super absorbent Polymer (SAPs were added at a rate of 0 – 0.6 wt % of cement and bulk density 0.85 g/cm3). The SAPs are covalently cross-linked, they are acryl amide/acrylic acid copolymers. One type of SAPs are suspension polymerized, spherical particles with an average particle size of approximately 200 mm, another type of SAP is solution polymerized and then crushed and sieved to particle sizes in the range of 125–250 mm. It was seen that more than 50% swelling occurs within the first 5 min after water addition. Based on the results obtained, the following conclusions were drawn, water retention for the concrete mixes incorporating a self-curing agent is higher compared to conventional concrete mixes, as found by the weight loss with time. The optimum dosage is 0.3 % addition of SAP leads to a significant increase in mechanical strength of concrete. Performance of the self-curing agent will be affected by the mix proportions mainly the cement content and w/c ratio.Compressive strength of self-cured concrete for the dosage of 0.3% was higher than conventional concrete. Split tensile strength of self-cured concrete for a dosage of 0.3% is higher than conventional concrete. Flexural strength of self-cured concrete for a dosage of 0.3% is lower than conventional concrete. There was a gradual increase in the strength for dosage from 0.2 to 0.3 % and later gradually reduced. Self-cured concrete using SAP was more economical than conventionally cured concrete. In this study cubes were casted and kept for curing in room temperature; self-cured member is needed to be checked. The effectiveness of internal curing by means of SAP applied to concrete was the highest if 45 kg/m3 water was added by mean of 1 kg/m^3SAP.Concrete cured internally using SAP attained more compressive strength than conventionally cured concrete for all proportions. (0.1% - 0.6%) and the optimum dosage of SAP for internal curing was found out to be 0.3% by weight of cement.

Saravanakumar et al. (2017) investigated an experimental study on fibre reinforced self consolidatingself-curing concret**e** (SCC). In this investigation workability tests for SCC, the compressive strength of SCC, workability and mechanical properties of fibre reinforced self Consolidatingself-curingconcrete and strength properties of fibre reinforced self consolidatingself-curing Concrete (SC-SCC) were carried out as per

European Federation of National Association Representing Concrete (EFNARC) guide line provisions. The cube has been cast for conventional and SCC for M40 grade of concrete. Then the cube has been tested for 28 days curing. The mix trial no-9 produces better results among all the mix. The materials used were 53 grade OPC having specific gravity of 3.15 conforming to IS 8112, fine aggregate having specific gravity of 2.74 and fineness modulus of 2.67, Coarse aggregate having maximum size of 12mm and specific gravity of 2.74, Potable water, Superplasticisers(Conplast SP 430), Silica fume of specific gravity 2.34 were used in this study.Based on the experimental investigation and test results obtained, the following conclusions are drawn,the fresh concrete test results are within the limits of SCC i.e., flow ability, passing ability and resistance against segregation. The compressive strength of trial 6, trial 7, trial 8, trial 9, trial 10, trial 11 and trial 12 was achieved for grade of concrete within 7- days. It was also found that the ratio of strength gain is early.

Shikha Tyagi (2015)Studiedanexperimental investigation of self-curing concrete incorporated with polyethylene glycol as a self-curing agent .This study involves the use of shrinkage reducing admixtures like Polyethylene Glycol (PEG 400) as internal curing compound to study the effect of different curing compound (PEG400) on the strength properties of concrete, this curing compound used in concrete which helps in self-curing and helps in better hydration and hence good compressive strength. They trap the moisture within the structure and prevent it from evaporation which normally occurs due to the hydration process. The effect of the curing compound on workability (slump and compaction factor) and compressive strength were studied. In this study the percentage of PEG by weight of cement from 0% to 2% as the dosage of internal curing compound was fixed .The test results were studied both for M25 and M40 mixes. It was found that through this experimental study PEG 400 help in self-curing by giving strength compared with that of the conventional curing method and also improved workability.The materials used were OPC (53 grade) conforming to IS: 12269-1987, fine aggregate having specific gravity of 2.6 conforming to IS: 383-1970 in zone II, coarse aggregate having specific gravity of 2.7 with maximum aggregate size of 20mm conforming to IS: 383-1970,Potable water and Polyethylene Glycol-400(PEG-400) as an internal curing compound.From the experimental tests results and observations done, the following conclusions are made,compressive strength of various mixes for M25 and M40 grade of concrete concluded that the compressive strength of mixes using self-curing compounds (PEG-400) are at par with that of the concrete with conventional curing and the optimum dosage of PEG400 for maximum strength was found to be 1% for M25 and 0.5%for M40 grade. As the percentage of PEG400 increased slump increased forM25 and M40grades of concrete. From the workability test results, it was found that the self-curing agent improved workability. It was seen that the minimum strength as per the codal provisions had been achieved by the specimens cured through curing compounds. The strength achieved by the PEG400 is comparable for both types of mix i.e. M25 and M40.

T.Naresh(2017)studiedonself-curing concrete incorporated with polyethylene glycol as self-curing agent" **.**In this study, the effect of curing compound on workability (slump and compaction factor) and compressive strength were studied to determine the effect of different curing compound (PEG400) on the strength properties of concrete. In this experimental work the percentage of PEG by weight of cement from 0% to 2% as the dosage of internal curing compound was fixed. The test results were studied both for M25 and M40 mixes. It is found through this experiment study that PEG 400 help in self-curing by giving strength on par with that of the conventional curing method and also improved workability. The materials used were OPC (53 grade) conforming to IS: 12269-1987, fine aggregate having specific gravity of 2.6conforming to IS: 383-1970 in zone II, coarse aggregate having specific gravity of 2.7 with maximum aggregate size of 20 mm conforming to IS: 383-1970, potable water and Polyethylene Glycol-400(PEG-400) as an internal curing compound.Based on experimental tests results and observationsthefollowing conclusions were made,as per the results obtained, the compressive strength of various mixes for M25 and M40grade of concrete we conclude that the compressive strength of mixes using self-curingcompounds(PEG-400) are at par with that of the concrete with conventional curing. The optimum dosage of PEG400 for maximum strength was found to be 1% for M25 and 0.5%forM40 grade. As a percentage of PEG400 increased slump increased forM25 and M40grades of concrete. From the workability test results, it was found that the self-curing agent improved workability and the minimum strength as per the codal provisions has been achieved by the specimens cured through curing compounds. The strength achieved by the PEG400 is comparable for both types of mixes(M25 and M40).

Dadaji (2017)studied on self-curing and self-compacting concrete using polyethylene glycol**.** This investigation was aimed to utilize the benefits of both self-curing as well as self-compacting. It involves the use of self-curing agent viz, Polyethylene Glycol (PEG) of molecular weight 4000 (PEG 4000) for dosages ranging between 0.1 to 1% by weight of cement added to mixing water. Two mixes with different w/c ratio were considered in the investigation. Workability tests i.e. slump flow, T50, V-funnel, J-ring, L-box were conducted on the fresh concrete whereas water retention and compressive strength were evaluated to determine the properties of hardened concrete. The comparative studies were carried out for water retention and compressive strength for conventional SCC and self-cured SCC. The compressive strength of self-cured self compactingconcreteare comparable with traditionally cured specimens at lower w/c ratio whereas does not provide satisfactory results at higher w/c ratio.The different materials used in this investigation were: cement,fine aggregate, coarse aggregate, polyethylene glycol(PEG-4000), Polycarboxylate Ether (superplasticizer), fly ash,silica fume and water.After analyzing the results obtained from the experimental programme, the following conclusions were made regarding the use of PEG-4000 in case of self-compacting concrete with low as well as high w/c ratios. The strength ofSelf-curingselfcompactingconcrete(SCC) with lower w/c ratio (Mix A) improves with the addition of PEG-4000 and is almost equivalent to wet curing, thus PEG-4000 inclusion proves to be beneficial. The optimum PEG dosage at lower w/c ratio was found to be 0.1% for Mix A. The compressive strength of self-curingselfcompactingconcrete(SCC) with high w/c ratio (Mix B) improves with the addition of PEG-4000 and is higher than indoor curing at all dosages of PEG-4000. The optimum dosage was found to be 1%. Compressive strength ofself-curingselfcompactingconcrete(SCC) with high w/c ratio (Mix C) did not show favorable results and were observed to be less than indoor curing for all the dosages. Thustheaddition of PEG-4000 for high w/c ratio is insignificant.

Gopika et al.(2018)studiedonthe effect of self-curing agents on mechanical Properties of High-PerformanceConcrete.In this study shrinkage reducing admixtures (SRA) and polyethylene glycol is used as the self–curing agent. The main objective of the current study is to identify the suitable self-curing compound on the selected agents with optimum dosage for high performance concrete(HPC). It is also aimed to investigate the strength characteristics of HPC. The principle aim of the study was to find out the suitable SRA among Polyethylene Glycol (PEG 300, PEG 400 and PEG 600) and its optimum dosage on M60 grade concrete .For the study three self-curing agents namely polyethylene glycol (PEG) 300,400 and 600 with varying percentages are to beinvestigated. A comparison was made considering three curing conditions such as no external and internal curing, wet curing and self-curing. By selecting appropriate materials and controlling their amount, size, and porosity, highly efficient internal water curing can be ensured.The different materials used in this investigation were 53grade OPC having a specific gravity of 3.125 and standard consistency of 32.5%, fine aggregate with specific gravity of 2.605, natural coarse aggregate with a maximum nominal size of 20mm and the specific gravity of 2.65, fineness modulus of 6.19 and water absorption of coarse aggregate was 0.44respectively, silica fume with a specific gravity of 2.2, Polyethylene Glycol (PEG) and ceroplastic 300 superplasticizer. Based on the experimental results presented in this study, the following conclusions were drawn as follows,Compressive strength and tensile strength of all the concrete studied increases with time in different rates under different curing conditions. Compressive strength systematically increases with shrinkage reducing admixtures (SRA) of Polyethylene Glycol (PEG) compounds, which may be attributed by the continuation of the hydration process. At the age of 28 days, SRA added concrete is found to show better compressive and tensile strength characteristics than conventionally cured concrete. For PEG 300, the optimum dosage was found to be 1%. Whereas, PEG 400 and PEG 600 had shown optimum values at 1.5%. The percentage increase in compressive strength on addition with PEG 300, 400 and 600 was found to be 4.11%, 5.69% and 8.42% respectively when compared to the conventionally cured concrete. The Compressive strength of conventionally cured specimen is significantly higher than specimen with no external and internal curing and the percentage increase was found to be 13.33%. The percentage increase in tensile strength was found to be higher while incorporating PEG 300, 400 and 600 to HPC and the increment was about 4.11% for PEG 300, 5.69% for PEG 400 and 8.42% PEG 600 than the conventionally cured concrete. Tensile strength of conventionally cured specimen is higher than those with no external and internal curing and the percentage increase was found to be 17.44%. The mechanical properties of self-cured HPC were superior while using SRA of PEG 600. Also increasing the amount of SRA can lead to a reduction of strength for all type of PEG studied. It was observed that self-curing concrete resulted in better hydration with time under drying condition compared to conventional concrete.

Amal Viswam and Arjun Murali (2018)studied on self-curing concrete to compare conventionally curing concrete and self-curing concrete (internal curing concrete).In this study the compressive strength of self cured concrete and conventionally cured concrete were determined.Shrinkage reducing agents like Polyethylene-Glycol (PEG) and lightweight aggregates such as Leca and silica fume wereused to achieve effective curing results**.**Based on this research work, the following was concluded from the study in spite of the scattering of testresults, water retention for the concrete mixes incorporating self-curing agent is higher compared to conventional concrete mixes, as found by the weight loss with time. Self-curing concrete resulted in better hydration with time under drying condition compared to conventional concrete. Water transport through self-curing concrete was lower than air-cured conventional concrete. Slump value increases with an increase in the quantity of PEG. Self-curing concrete is the answer to many problems faced due to lack of proper curing .It was found that the compressive strength of self cured concrete was high than conventionally cured concrete.

Jayeshkumar (2014) studied on “self-curing concrete in the construction industry”.In this research paper, theindividual effect of admixture Polyethylene Glycol (PEG600 & PEG1500) oncompressive strength by varying the percentage of PEG600 andPEG1500 by weight of cement 0.5%, 1.0%, 1.5% and 2% werestudied. The study shows that PEG600 and PEG1500 could helpin gaining the strength of conventional curing. The different materials used in this investigation were 53 grade OPC, fine aggregate, the coarse aggregate of the maximum coarse aggregate size used is 20 mm, Polyethylene Glycol and potable water.It was also foundthat 1% of both PEG600 and PEG1500 by weight of cement wasoptimum for M25 grade concrete for achieving maximumstrength without compromising workability. Compressive strength of self-curing concrete is increased by applying self-curing admixtures. The test resultindicates that the use of water soluble polymers in concrete hasimprovedthe performance of concrete.Thecompressivestrength of the concrete mix increased by 37% by adding 1.0% of PEG600 and 33.9by adding 1.0% of PEG1500 as comparedto the conventional concrete.The optimum dosage of PEG600 for maximum compressive strength was found to be 1% byweight of cement for M25 grade of concrete. The optimum dosage of PEG1500 of maximum compressive strength wasfound to be 1% by weight of cement for M25 grade of concrete. Self-curing concrete is the best solution to the problemfaced in the desert region and faced due to lack of proper curing.

Mousa Magda et.al (2014)studied on the mechanical properties of self-curing concrete incorporated with self-curing agents. The strength of concrete was analysed and the addition of silica fume on the properties was studied. The concrete used polyethylene-glycol as self-curing agent shows improved properties than concrete with saturated Leca. For their study, two materials were selected as self-curing agents such as pre-soaked lightweight aggregate (Leca) or polyethylene-glycol with different dosages and the addition of silica fume was studied. The effect of different dosages of the self-curingagentswasanalysed and the optimum values are identified. In all cases, either 2% PEG or 15% Leca was the optimum ratio compared with the other ratios. Results of their study demonstrated that a significant improvement took place in the physical properties studied for self-curing concrete with poly-ethylene glycol (Ch.) as self-curing agent. The use of self-curing agents (polyethylene-glycol or saturated Leca) in concrete mixes improves the mechanical properties of concretes under air curing regime which may be attributed to better water retention and causes a continuation of the hydration process of cement paste resulting in fewer voids and pores and greater bond force between the cement paste and aggregate. The improvement in the mechanical properties of self-curing concrete was superior while using a self-curing agent of chemical type (Polyethylene-Glycol) compared to aggregate type (saturated

Leca). Also the test results of this investigation illustrate that, the indirect tensile strength was in the range of 6.4% to 8.5% fcu for all self-curing concrete and was perfectly correlated with compressive strength. The test on flexural strength represented 10–14.5% of compressive strength of all self-curing concrete type. Good correlation was observed between flexural and compressive strength.

2.2.2 Durability and strength characteristics for conventional and self-curing concrete

Akanksha Anantrao Patil(2014)studiedthe comparative study on durability of self curedself-compacting concrete (SCC) and normally cured self-compacting concrete (SCC).This paper reports the results of a research study conducted to evaluate the effect of the self-curing method on the durability of self compacting concrete (SCC). Cube specimens were prepared and cured by covering them with a curing compound and normal water. The sorptivity and acid attack tests were conducted on the concrete specimens and compared the durability of normally cured SCC and SCC cured with self-curing material i.e. wax based, white pigmented (Concure WB of specific gravity : 1 to 1.01 g/cc, colour : bulk liquid white, covers 3.5 to 5.0 m2/litre and shelf life– 12 months) and membrane forming concrete curing compound (Materkure107i of type II, class A. BS 7542: 1992, colour : white liquid, shelf life is 12 months and the application rate of 5-6 m2/litre). Other materials used in this study were 53 grade OPC with of specific gravity 3.15, fine aggregate having specific gravity 2.60 and fineness modulus 2.783, coarse aggregate having a specific gravity of 2.9, silica fume having specific gravity 2.38, ordinary potable water and SuperplasticisersGLENIUM B233complies with IS: 9103– 1999 were used for their study. From the results obtained, it was known that normal curing method seems to be the best method for curing giving maximum strength and durability. It has also shown that by using curing compounds, we can achieve almost 90% strength and durability achieved by normal curing method without much attention as there is not major strength loss. From the test results it has been observed that curing compounds does not have any adverse effect on the durability of concrete. The following conclusions were drawn from the experimental investigation,self-curing concrete with curing compound Concure WB gives about 10% less compressive strength than normal water curing. Self-curingconcrete with curing compound Materkure107i gives about 15% less compressive strength than normal water curing. In areas with a shortage of water, the sustainability of water can be achieved by using suitable chemical compounds for curing of concrete. The durability of concrete is not affected much by using chemical compounds for curing performance of both the curing compounds and it was almost the same for self - compacting concrete. The coating of curing compound could not be removed completely; hence the ingress of the acid was obstructed reducing the mass loss and strength loss. Through the final strength was less than that of the water cured specimens.

Sarita Sharma and Devesh (2018) studied onstrength and durability of high volume fly ash concrete with different self-curing agents. In this investigation polyethylene glycol and spinaciaoleracea were used as self-curing agents in high volume fly ash concrete to study its effect on workability, strength and durability of concrete when internally cured by them. The presented paper was focusing on M30 concrete mix with 50 percent fly ash replacement to form high volume fly ash concrete. The optimum dosage of poly ethylene glycol and spinaciaoleracea was taken as 0.5% and 0.8% by the weight of the binder. The slump test showed, it fulfills the medium range workability. Compressive strength of conventionally cured high volume fly ash concrete was less then self cured once and performance for the durability of self cured concrete was good for the given conditions.The different materials used in this study werePortlandpozzolana cement of specific gravity 3.1, fly ash of specific gravity 1.90-2.55, coarse aggregates of maximum size 20mm, fine aggregate after conforming to zone II of IS: 3831970,Polyethylene glycol of specific gravity 1.12 and spinaciaoleracea as self-curing agents. From the results achieved, the following conclusion was taken. The workability, strength and durability studies done by using polyethylene glycol and one biomaterial spinaciaoleracea as the self-curing agent showed positive results because of the presence of OH ions in self-curing concrete. Moreover, spinaciaoleracea was vegetative eco-friendly and very cheap self-curing agent compare to polyethylene glycol which results in an overall decrease in the cost of the project by reducing potable water used during curing. Self-curing concrete was an alternative to conventional concrete in desert regions where scarcity of water is amajor problem.

Kumar amgoth ram (2016)studied onthedurability of self compacting and self-curingconcrete.This investigation involved the use of different self-curing compounds viz, Polyethylene Glycol (PEG) of molecular weight 4000(PEG 4000) and 200 (PEG 200), liquid paraffin wax light and liquid paraffin wax heavy for dosages ranging between 0.1to 1% by weight of cement added to mixing water. Other materials used in this investigation were 53 grade ordinary Portland cement having a specific gravity of 3.14, fine aggregate with specific gravity of 2.65, the coarse aggregate specific gravity of 2.8,superplasticizer , silica fume with specific gravity in the range of 2.2 to 2.3, fly ash of specific gravity 2.17and potable water. Three mixes A, B and C with different w/c ratio were considered in this investigation.Workability tests i.e. slump flow, T50, V-funnel, J-ring, L-box were conducted on the fresh concrete wherecompressive strength, the acid attack and sorptivity were evaluated to determine the durability properties of hardenedconcrete.The comparative studies were carried out for workability, compressive strength, acid attack and sorptivityforconventional SCC and self-cured SCC.The durability properties of self-cured SCC were compared with traditionally cured specimens.Based on the experimental results and analytical investigations done, the following conclusions have been drawn,there was a decrease in compressive strength of self-curingselfcompactingconcrete(SCC) with the increase in the percentage of curing compounds for a higher grade and higher dosage of curing compound is required for lower grades of self-curing SCC.Resistance against acid attack decreased with increase in percentage dosage of self-curing compounds irrespective of grades and 0.5% was an optimum dosage to get better resistance against acid attack for all curing compounds.Sorptivity decreased with a decrease in dosage of PEG in both low and high molecular weights of PEG andsorptivitywas lowest in higher grades of concrete and it was true for every percentage replacement of all the curing compounds.

P.B.Narandiranstudied on strength and durability properties of self-curingconcrete.In this study, the aim was to determine the effect of Polyethylene Glycol (PEG 600) on strength and durability characteristics of self-curing concrete. The mechanical properties of concrete such as compressive strength, split tensile strength and the durability properties of concrete was obtained by conducting acid resistance, alkalinity measurement by using the varies percentage of PEG from 0% to 1% by weight of cement for M20 grade of concrete. To determine the water retention capacity for the concrete mixes incorporating self-curing agent was to be compared with conventional concrete.Theadmixture usedwas the extract from polyethylene glycol 600 at 0 %- 10 % by weight of cement. Polyethylene Glycol (600) was a low-molecularweight grade of polyethylene glycol and it was a clear, colourless, viscous liquid, then due to its low toxicity, PEG 600 is widely used in a variety of pharmaceutical formulations.From the results obtained, the following conclusion was taken,the rate of evaporation was reduced and the water retention capacity has been increased by increasing the percentage of PEG and the optimum dosage of PEG600 for compressive strength was found to be 0.8% for M20 grades of concrete as percentage of PEG600 increased slump increased for M20 grades of concrete. Split tensile strength of self-cured concrete for the dosage of 0.8% was higher than water cured concrete. Strength and durability properties of self-curing concrete were compared with conventional concrete and the durability test of self-cured concrete for the dosage of 0.8% was higher than water cured concrete. Based on the various studies, it was proposed to use PEG as a self-curing agent. Then self-curing concrete is the answer to many problems faced due to lack of proper curing.

Bashandy A. et al(2017) studied on the durability of recycled aggregate self-curing concrete. In this investigation, the durability of recycled aggregate self-curing concrete studied under the attack of sulfates and chlorides. The effect of sulfates on compressive, splitting tensile and flexure strengths at different ages (2, 4 and 6 months) were studied. The effect of chloride attack (as 8% concentrated sodium chloride solution) was studied on bond and flexural strengths at different ages (1 and 2 months) and also, the flexure behavior of the recycled aggregate self-curing reinforced concrete beams was studied individually under the effect of chloride attack after different exposure conditions. Ordinary Portland cement, drinkable clean water, fine aggregate with a specific gravity 2.6, recycled coarse aggregate with a maximum nominal size of 20 mm, steel rebars of 8 mm diameter with yield strength of 240

MPaand tensile strength of 350 Mpa, water reducing admixture and self-curing agent**(**PolyethyleneGlycol PEG400) were used in this investigation. The test results indicated that recycled aggregates (such as crushed concrete and crushed red bricks) could be used in self-curing concrete with satisfied durability characteristics under chlorides and sulfate attacks. Dolomite then crushed concrete followed by crushed red bricks can be used as coarse aggregates for self-curing concrete.The durability of the self-curing concrete cast using dolomite aggregate was higher than both self-curing concretes with crushed concrete and crushed bricks as aggregates. The compressive, tensile splitting and flexure strength values increase under the effect of sulfates at 2 and 4 months, then starts to decrease at 6 months (in the range of this study). It was observed that the stiffness decrease when the ductility ratio increases and the rate of decrease were faster when the loading rate was faster.

Dayalan J (2016)studiedoncompressive strength and durability of self-curing concrete. The objective of this study was to determine the various properties of SCC (self-curing concrete) for M25 grade concrete by mixing different dosages of super absorbent polymer into concrete, to determine the weight loss and physical properties of self-curing concrete also compressive, split tensile and flexural strength of SCC and then to determine the short term resistance to acid. In this study, self-curing concrete (SCC) has been developed and an attempt has been made to develop self-curing concrete by using super absorbing polymers. SCC was a very promising technique that can provide additional moisture in concrete for continuous and effective hydration. By the introduction of curing agents into concrete, additional moisture can be maintained. Super absorbent polymers (SAP) are polymeric materials which have the ability to absorb a large amount of moisture from the surroundings (concrete). The concrete mix of M25 was proportioned. Workability, strength characteristics and acid resistance of the concrete with 0, 0.12, 0.24 and 0.48% of super absorbent polymer by the weight of cement were carried out. The different materials used were 53 grade ordinary Portland cement having a specific gravity of 3.15, natural river sand having specific gravity of 2.66, crushed granite aggregate having specific gravity of 2.69, superabsorbent polymers (SAP) having bulk density of 0.85 and ordinary portable water.Based on the results found in this study, the following conclusionwasdrawn,water retention for the concrete mixes incorporating self-curing agent was higher compared to conventional concrete mixes, as found by the weight loss with time but the performance of the SCC was affected by the amount of super absorbent polymer added in the mix by % weight of cement. The use of super absorbent polymer (0.48% by the weight of cement) as self-curing agent provides higher compressive, tensile as well as flexural strength than the strength of conventional mix. It was found that concrete with this self-curing agent SAP, exhibits higher strength and acid resistance compared to the conventionally cured concrete.

2.2.3 Effect of self-curing compounds on strength and durability of concrete

T.Suresh and Sreenivasa kumar (2015 **)** studied on effect of self-curing compound on strength and durability of M25 Mix concrete. In this presented study, the effect of admixture (PEG-200) on compressive strength, split tensile strength at one percentage for M25 mix was studied and it was compared with the properties of PEA (Poly ethylene alcohol).The different materials used in this investigation were 53 grade OPC, fine aggregate from a river conforming to zone III according to IS: 383-1970, coarse aggregate of maximum 20 mm, Polyethylene Glycol-200 (PEG-200) having specific gravity of 1.126 and potable water. The optimum strength values for both self-curing agents were found among both agents PEG-200 andPEA.It was found that Poly Ethylene Glycol-200 was a good self-curing agent when compared with Poly ethylene alcohol because in the durability and normal compressive strength aspects it was giving good results when compared with both conventional concrete and Poly ethylene alcohol (PAE), also at the place of water scarcity areas these type of curing agents will give a better result. This study was shown about a clear cooperate picture about the strengths of PEG-200 and PEA and its stress strain behaviour also shown clearly. This study also gives a clear notation on durability.

Tapeshwar and Amjad Abass (2017)studied the effect of self-curing compound on the properties of concrete. This study explored the suitability of internal curing for solving shrinkage problems and improves the performance of self- cured concrete. In this research, the effect of self-curing admixture (Poly ethylene glocol-4000) on the concrete was investigated.A comparison has been made between the concrete mixes with no curing, normal curing and concrete with self-curing admixture. The materials consisted of 43 grade ordinary Portland cement having specific gravity of 3.15, river sand of specific gravity 2.83 and fineness modulus 2.67, crushed coarse aggregate having maximum size of20mm, Polyethylene Glycols (PEG) as self-curing agent and potable water. They used self-curing admixture in different prepositions (0.5%, 1.0%, 1.5%, and 2.0% of PEG-4000 by weight of cement). The experimental results presented in this research elaborate that the optimum dosage found was 1.0% of PEG-4000 by weight of cement, where concrete has higher desired properties. It was seen that effect of internal curing agent and its combination with concrete influence on the strength properties, clearly shows that self-curing agent (PEG) can be used as an alternative to the general curing of concrete. It was clearly demonstrated that self-curing concrete could be used in the places where normal curing is not done properly like in arid areas, high rise buildings , areas were supervision is not done regularly, highwayswhere the surface is exposed to hot environmental conditions.

Daliya Joseph and Belarmin (2016)studiedtheeffect of self-curing agents on mechanical properties of concrete**.** In this research paper, the individual effect of curing agents like PEG 4000 & PVA on strength properties by varying the percentage of PEG4000 and PVA by weight of cement 1.0%, 2% and 3% were studied. The study shows that PEG4000 and PVA could help in gaining the strength of conventional curing concrete. The materials used were 53grade Sankar Portland pozzolana cement having specific gravity of 2.7, fine aggregate of specific gravity 2.76, coarse aggregate having maximum size 20 mm and specific gravity of 2.54, Polyethylene Glycol-4000(PEG4000), Poly Vinyl Alcohol (PVA)and potable water. Based on experimental results found, the following conclusions were drawn, the self-curing agent PVA was found to be effective than PEG. From the strength test done, all the strength properties were found to be higher for PVA. As the percentage of PEG4000 increases the slump value also increases but in case of PVA the increase in percentage caused decrease in slump value. From compressive strength, splitting tensile strength and flexural strength test results, it was found that self-curing concrete has more strength results than that was found in water cured concrete but increase in percentage of self-curing agent resulted in decrease in strength properties of concrete. The cement content and w/c ratio affect the performance of self-curing agent to a large extent.It was found that 1% of both PEG4000 and PVA by weight of cement was optimum for M30 grade concrete for achieving maximum strength without compromising workability. The test results showed that self-curing concrete is the best option in places where water scarcity exists.

Shabarish Patilet al(2016)studiedoneffect of curing compounds on strength and durability of concrete mixes. In this study, an attempt has been made on the study of effect of using curing compounds on strength and durability properties of different concrete mixes. Mix proportions arrived for M20, M30, conventional M40 and M40-self compacting concrete. The materials consisted of 43 grade ordinary Portland cement confirming to IS: 8112-1989, river sand of specific gravity 2.6 and fineness modulus 2.17 confirming to zone III of IS: 383: 1970, crushed granite stone chips (20mm down) of specific gravity 2.7 and fineness modulus of 6.65, fly ash and water. The cubes strengths were tested on 7 and 28 days as a strength parameter and the cylinders were tested for durability aspect by rapid chloride penetration test (RCPT). Concrete specimens were subjected to curing conditions such as wet curing for 28 days and application of curing compound after two days of wet curing. The curing compounds used in the study were wax based compounds**.** From experimental results obtained, the following conclusions were taken,irrespective of curing compounds employed and methodology of the application used, the water ponding method gives the higher strength and lower permeability than with curing compounds i.e. efficiency of curing compounds as compared with wet curing was less than 100% both for strength and durability. The performances ofboth the curing compounds were almost same, however the curing compound CC-2 performed better than CC-1 under both the curing conditions for all the three normal concrete mixes- i.e. M20, M30 and M40.As the compressive strength of mix increases the penetrability for chloride ions decreases. The chloride ion penetrability was almost 50% less for SCC-M40 mix, compared to normal M40 mix.

M. Naderi et al**s**tudied oncomparison of different curing effects on concrete strength**.** The purpose of this investigation was to conduct a laboratory test program on how much different curing conditions affect the attainable strength of concrete. To achieve this purpose, a laboratory test program was conducted. The laboratory program consisted of casting 150 mm by 150 mm concrete cubes using eightdifferent mix designs and subjecting them to six different curing conditions. In order to investigate the influence of curing conditions, on the compressive strength of concrete cubes for each mix design three cubes were chosen for every curing regime. The curing regimes employed wereimmersion in drinking water, covering with wet hessian and polythene sheet; keeping under dry laboratory conditions; keeping in open air; curing compound and steam curing. Except for steam curing system the specimens of which were tested at the age of three days, for all other curing conditions, the compression tests were performed at the age of 28 days. The materials used were ordinary Portland cement, natural zone II sand (fine aggregate), basalt aggregate withamaximum size of 20mm (coarse aggregate) mixed with sufficient drinking water and required additives where necessary. From the results presented and discussed in this paper, the following conclusions were made, the different curing systems have different effects on the compressive strength of concrete. The curing systems employed in this research, covering with wet hessian and polythene sheet produced the highest concrete compressive strength. It has been found that the curing system greatly influences the concrete strength. While the highest gain in compressive strength was recorded for cubes covered with wet hessian and polythene sheet, the lowest gain in compressive strength was recorded for the specimens cure using steam curing.

2.2.4 Scanning Electron Microscopy (SEM)forconcrete

Adithya Saran (2017) studied on the experimental study on Sustainable High Performance Concrete and its microstructural behaviour (SEM). The major concrete constituents were replaced with alternative materials. Cement was partially replaced with Fly ash (30% and 35%) and Silica fume (7.5 % and 10%) and fine aggregate were entirely replaced with manufactured sand. Coarse aggregate was partially replaced with recycled aggregate by 30%, 40% and 50% .Seven concrete mixes were prepared and casted into cubes. The concrete cubes were tested for compressive strength after 28 days curing and a considerable value of compressive strength was observed in Mix 4 (7.5 % S.F+ 30% F.A+ 40% RCA).From SEM micrograph of Mix 4, The chemical reaction of silica fume and fly ash with Portlandite (Ca (OH) 2) leads to production of additional C-S-H gel which fairly improves the strength of Mix-4. The range of scale used in SEM analysis was 5 μm with the resolution of x5000. From the test results of compressive strength, it was observed that the replacement of concrete ingredients fairly improves on the strength of concrete mixes. The strength of Mix-4 was not up to the expected level but, the mix is possibly suitable for normal concreting works. In SEM Observations, the existence of mineral elements and their reactions with the supplementary materials are studied which gives the initiative to understand the microstructure of the concrete mixes. Based on the comparison of the microstructure of concrete mixes, it is clear that the hydration process in the mixes with supplementary materials was different from conventional concrete mix. In Mix-4, the hydration process was quiet similar to the normal concrete mix but, the development of C-S-H gel in the mix was quiet lesser compared to the normal concrete mix (Mix-1).

The electron microscope was apparently first used by Eitel (1941, 1942) and by Radczewski*et al.* (1939) to study the hydration process of concrete. Le Chattelier (1882) was among the first to apply the microscope to the study of cementitious materials. He used it to investigate the chemical and physical aspects of hydration and setting, rather than to study cracks. His efforts undoubtedly influenced later workers in their use of the microscope. Grudemo (1960) was another important pioneer in the use of high magnification, including the use of the electron microscope. Although most of these studies were not directly related to cracks, they led the way to later studies of cracks in which electron microscopy was a powerful tool. Tavasci (1941) successfully used the microscope to study the composition and structure of concrete, but not of cracks perse. His work, however, set the stage for the studies of cracks on the interior surfaces of cut specimens which were conducted in the 1960s.

CHAPTER 03

MATERIALS AND METHODOLOGY

3.1 GENERAL

In this chapter, the materials used for concrete preparation, production and the properties of the materials required for the concrete mix design are given and described in details. The different tests conducted on external self curing concrete and normal curing concrete within the methodology used for the tests are discussed in this section to understand the effect of concrete curing techniques on the strength characteristics of concrete when normal curing and external self curinghave been done in construction works. The followings are the methodologies adopted to achieve the objectives of this experimental works.

3.2 MATERIALS USED AND THEIR PROPERTIES

It is wellknown that the strength ofthe concrete is dependent on the properties of its ingredient materials. The present investigation was carried out to study the behavior of normal andexternalself cured concrete and their ingredient materials. In this experimental work, concrete mix design was carried out for M30 grade concrete. The following materials such as ordinary Portland cement (53 grade OPC confirming to Indian standard IS:12269: 1987), Portland pozzolana cement (PPC confirming to Indian standard IS:1489-1991(part I), river sand as fine aggregate, quarried and crushed stone as coarse aggregate, superplasticizer, curing compound and potable water are used to determine concrete strength while using different curing techniques. The mix proportioning was determined separately for OPC and PPC as they have different properties in order to compare their concrete strength characteristics.

The materials were individually taken from a single lot and stored properly throughout the programme and then were tested according to the Indian standard specifications to determine the various properties of concrete ingredient materials. The tests were carried out at the Concrete Laboratory of Civil Engineering Department, NITK Surathkal.

3.2.1 Ordinary Portland cement (OPC)

Cement is defined as the bonding and binding material in concrete production having cohesive and adhesive properties which makes it capable of joining uniformly the different construction materials and compacted assembly. Ordinary/Normal Portland cement is one of the most widely used types of Portland cement. Ordinary Portland Cement (OPC) is the most commonly used cement in general concrete construction when there is no exposure to sulphates in the soil or groundwater as per IS: 8112-1989.

The specific gravity, normal consistency, initial setting time, final setting time and compressive strength of cement were found according to Indian standard specifications and the results for the cement properties are shown below.

Table3.1 Basic properties of ordinary Portland cement (OPC)

SI. No.	Particulars (tests)	Results obtained	References
	Type of cement	53 grade OPC	IS: 12269
1	Normal Consistency	32 %	IS: 269 -1976
2	Specific Gravity	3.15	IS: 269 -1976
3	Setting time (in min)		IS: 269 -1976
	(a) Initial setting time	90 min.	Should be not less than 30 minutes
	(b) Final setting time	270 min.	Should not be more than 600 minutes
4.	Fineness	3913.90 cm^2/g	Blain’s air permeability test

3.2.1.1 Compressive Strength of Cement paste (OPC)

For this type of cement (53 gradeOPC**)**, compressive strength was determined for 3, 7 and 28 days and the average results of three specimens were used. The compressive strength of cement paste was calculated and determined using the formula shown below and the Size of the specimen was 50mm×50mm×50mm.

- **Compressive Strength of Cement** = Applied load /Cross-section Area of the Specimen(cube)

Figure3.1 Preparation and testing of compressive strength of cement paste for OPC

3.2.2 Portland pozzolona cement (PPC)

Portland pozzolonacement(PPC) is manufactured by inter grinding OPC clinker with 15-35% of pozzolonic materials. Pozzolans are essentially siliceous or aluminous materials, which in itself possess no cementitious properties which are in finely divided form and in the presence of moisture, react with calcium hydroxide liberated in the hydration process at ordinary temperature to form compounds possessing cementitious properties. The pozzolonic materials generally used are fly ash or calcined clay. PPC produces less heat of hydration and offers greater resistance to attach of aggressive environment, gives long-term strength and enhances the durability of the structures.

In the present research project work, Portland pozzolona cement-fly ash based (ultra tech cement) confirming to Indian standard IS: 1489-1991(part I**)** has been used to compare strength characteristics for conventional and external self curing concrete. The results from the various tests on PPC are given and were conducted to obtain properties of cement as tabulated below. The Size of the specimen was 50mm×50mm×50mm.

Table3.2 Basic properties of Portland pozzolonacement (PPC)

SI.No	Particulars (tests)	Results obtained	References
	Type of cement	PPC	IS: 1489-1991
1	Normal Consistency	36%	Is: 1489-1991
2	Specific Gravity	2.85	Is: 1489-1991
3	Setting time (in min) (a) Initial setting time (b) Final setting time	 55 min. 170 min.	Should be not less than 30 minutes Should not be more than 600 minutes
4.	Fineness	3478.29 cm^2/g	Blain's air permeability test

3.2.2.1 Compressive Strength of Cement paste (PPC)

In this type of cement, compressive strength was determined for 3, 7 and 28 days and the average results of three specimens were used. The compressive strength of cement paste was calculated and determined using the formula given below and the size of the specimen was 50mm×50mm×50mm.

- **Compressive Strength of Cement**= Applied load /Cross-section Area of the Specimen(cube)

Figure3.2 Preparation and testing of compressive strength of cement paste for PPC

3.2.3 Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. The water used for mixing and curing should be clean and free from harmful materials and substances that may be deleterious to concrete properties and steel. Portable water is generally considered satisfactory for concrete mixing process. The PH value of water to be used should not be less than six. The portable water available in the laboratory taps conforming to the requirements of water for concreting and curing as per IS: 456-2000 was used in this project work for concrete production process.

3.2.4 Super plasticizer

Super plasticizers are the water reducing admixtures as per IS: 9103. Self curing concrete is nothing but highly water reduction and concrete strength behaviours. For obtaining this type of concrete high range water reducing admixtures (CONPLAST SP430) was used as a super plasticizer for the present investigation. The March cone test was conducted to determine its optimum dosage of super plasticizer (SP). The optimum dosage ofConplast SP430 is best determined by site trials with the concrete mix which enables the effects of workability, strength gain or cement reduction to be measured. As a guide, the rate of addition is generally in the range of 0.5 - 2.0 litres /100 kg of cement (ie 0.5 % - 2.0% by mass of cementinious material) .Based on experience adopted, the quantity of superplasticizer used is 1.5% by mass of cement for OPC and 2.0% for PPC concrete mixes.

Table3.3 Properties of CONPLAST SP430 (super plasticizer)

Properties of super plasticizer (CONPLAST SP430)	
Appearance	Brow liquid
Specific gravity	Typically 1.20 at 30 ^{0}C
Chloride content	Nil to BS 5075
Air entrainment	Typically less than 2% additional air is entrained at normal dosage.
Alkali content	Typically less than 72.0g.Na_2O equivalent/litre of admixture. A fact sheet on this subject is available

3.2.5 Curing compound

Description

Concure WB (FosrocConcure WB) is a white, low viscosity wax emulsion which incorporates a special alkali reactive emulsion breaking system. This system ensures that the emulsion breaks down to form a non penetrating continuous film immediately upon contact with a cementitious concrete surface. This impervious film prevents excessive water evaporation which in turn permits more efficient cement hydration, thus reducing shrinkage and increasing strength and durability of concrete. Once formed, the membrane will remain on the concrete surface until eventually broken down and eroded by natural weathering. Where it is required to apply a further treatment to such concrete surface, it may be necessary to remove the membrane remaining after curing by wire brushing or other mechanical means.

The use of curing membranes on internal floor slabs is generally to be avoided where additional surface finishes are to be applied. Concure WB is however ideal where the concrete surface of a floor slabs is to be left as 'finished'.

3.2.4.1 The properties of Curing Compound used (Concure WB)

The properties of Concure WB curing compound used are discussed bellow.

Table3.4 Properties of concure WB curing compound

Properties of Concure WB	
Curing efficiency	Concure WB curing agent complies with the internationally recognized ASTM C309-90standard
Specific gravity Colour	1 to 1.01 g/cc Bulk liquid White
Covers	3.5 to 5.0 m2/litre
Shelf life	12 months

3.2.4.2 Instructions for use and application

Exposed concrete slabs : Concure WB should be spray applied on to the newly placed concrete slab as soon as possible after it is free from visible surface water, e.g. typically 1 to 2 hours after placing.

Shuttered and precast concrete : Concure WB curing agent should be spray applied to all surfaces as soon as formwork has been removed or the element demoulded and do not apply if bleeding water is forming or is present on the concrete surface. In all cases the nozzle of the spray should be held approximately 450mm from the concrete surface and should be passed back and forth to ensure complete coverage. The pump pressure should be maintained at a level to produce a fine spray ensuring complete coverage of the surface and also it can be applied by brushing for the small concrete surface.

After spraying, no further application of water or other material is necessary to ensure continued curing. The concrete surface should not be disturbed until it has sufficient strength to bear surface loads. The applied film should not be trafficked until it is fully dry, care should also be taken to ensure that the film is not subsequently broken.

Figure3.3 Preparation and application of Concure WB curing compound

3.2.6 Aggregates

Aggregates are inert granular materials such as sand, gravel or crushed stones that are an end product in their own right. They are also the raw materials that are an essential ingredient in concrete production. For a good concrete mix, aggregates need to be clean, hard, strong particles free from absorbed chemicals or coating of clay and other fine materials that could cause the deterioration of concrete. Aggregates are broadly classified into two types namely coarse aggregate and fine aggregate.

3.2.6 .1 Properties of the coarse aggregate and fine aggregate used

The specific gravity and fineness modulus of fine aggregate and coarse aggregate was found according to the norms of the Indian Standards as per IS: 383:1970.

1. FINE AGGREGATE

Natural river sand conforming to Indian standard with fraction passing though 4.75mm sieve (is called fine aggregates), having specific gravity of 2.58, fineness modulus of 2.84was used for this study. Locally available sand conforming to zone II as per IS: 383: 1970 was used as fine aggregates for this present research work. The sand was tested as per IS: 2386:1963 (IS: 2386 Part I 1963).The specific gravity of natural sand was found according to Indian Standards and was used throughout in preparing the required mix of concrete.

Sieve analysis of the fine aggregate was also carried out as per the Indian standards specifications to determine the grading zone. The particle size distribution and results of the sieve analysis are described below.

Sieve analysis of fine aggregates:

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (Part I) – 1963. In this study, the different sieves were used as standardized by the IS code and then pass aggregates through them and thus collect different sized particles left over different sieves.The results of the percentage cumulative passing of fine aggregate through various sieve size were compacted with grading limit chart for fine aggregate**.** IS:383–1970 shows that the fine aggregate taken for the present study comes under zone II.

Sieve analysis of fine aggregate

Weight of sample taken=1000 gm

Table3.5Results from sieve analysis for fine aggregate

SI.No	IS Sieve size	Weight retained(gm)	Cumulative Wt. retained	Cumulative% Wt. retained	% finer
1	10 mm	0	0	0	100.00
2	4.75 mm	61	61	6.10	93.90
3	2.36 mm	44	105	10.5	89.50
4	1.18 mm	336	441	44.10	55.90
5	600 µ	86	527	52.70	47.30
6	300 µ	192	719	71.90	28.10
7	150 µ	276	995	99.50	0.50
8	Pan	5		∑ =284.80	

Calculations:

Fineness modulus= ∑Cumulative% Wt. retained /100

= 284.80/100

=2.84

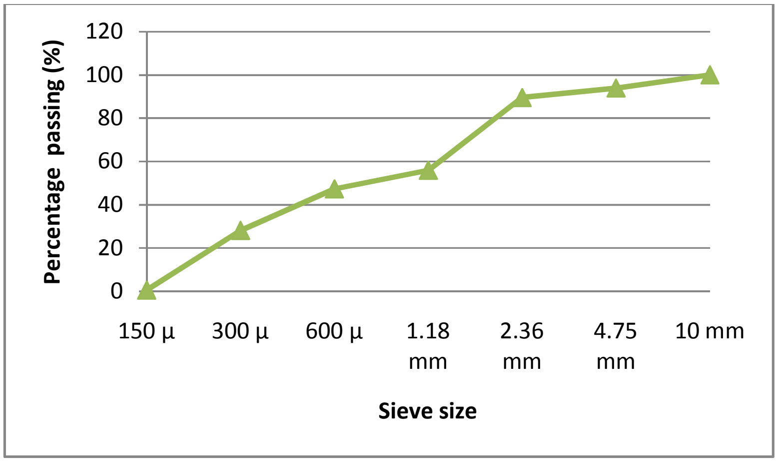


Figure3.4Particle Size Distribution for fine aggregates

The different physical properties of fine aggregate are given in the following table.

Table3.6 Properties of fine aggregates

SI.No	Particulars	Results/values obtained	References
1.	Fineness modulus	2.84	IS: 2386 (Part III)-1963
2.	Specific gravity	2.58	IS: 2836(Part III)-1963 IS: 383-1970 IS: 460-1962
3.	Grading zone	Zone-II	IS: 383-1963
4.	Water absorption	1%	---
5.	Moisture content	NIL	---

2. COARSE AGGREGATE

The aggregates retained on 4.75 mm sieve (called coarse aggregates), which are generally crushed stones aggregates having 20mm was used in the experimental work. The crushed stones aggregates used were 20mm nominal maximum size and were tested as per Indian standards.

The Coarse aggregates used in this study have the specific gravity of 2.70, fineness modulus of 7.76 and were tested as per IS Specifications IS: 383-1970.

The specific gravity of crushed stone aggregates of 20 mm and downsize was found according to the norms of Indian standards and were used for all concrete mixes. Sieve analysis of the coarse aggregates was also carried out as per Indian standards specifications. The sieve analysis results for coarse aggregates are shown in table below.

Sieve analysis of coarse aggregate

Weight of sample taken= 5000gms

Table3.7 Results from sieve analysis for coarse aggregate

SI.No	**IS Sieve size**	**Weight retained(gm)**	**Cumulative Wt. retained**	**Cumulative% Wt. retained**	**% finer**
1	40 mm	0	0	0	100.00
2	20 mm	3887.5	3887.5	77.75	22.25
3	10 mm	1044	4931.5	98.63	1.37
4	4.75 mm	66	4997.5	99.95	0.05
5	2.36 mm	25	5000	100	0.00
6	1.18 mm	0	5000	100	0.00
7	600 µ	0	5000	100	0.00
8	300 µ	0	5000	100	0.00
9	150 µ	0	5000	100	0.00
10	Pan	0		∑=776.33	

Calculations:

Fineness modulus= ∑Cumulative% Wt. retained /100

=776.33/100

= 7.76

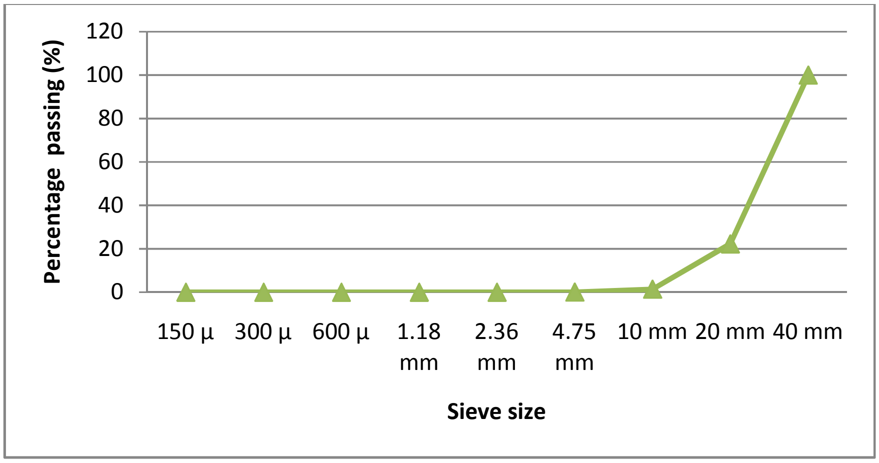


Figure3.5 Particle Size Distribution of coarse aggregates

The different physical properties of coarse aggregate are given in the following table.

Table3.8 Properties of coarse aggregate

SI.No	Particulars	Results/values obtained	References
1.	Fineness modulus	7.76	IS: 2386 (Part III)-1963
2.	Specific gravity	2.70	IS: 2836(Part III)-1963 IS: 383-1970 IS: 460-1962
3.	Water absorption	0.2%	---
4.	Moisture content	NIL	---

3.3 CONCRETE MIX DESIGN

3.3.1 Concrete mix design for both OPC and PPC mixes

Concrete mix design is defined as the process of selecting suitable ingredients materials of concrete and determining their proportions with the object of producing concrete of certain minimum strength and durability as possible. In this study, the mix proportions of the concrete were calculated according to IS: 10262:2009.

The mix proportions obtained are adjusted and determined for the field condition such as free surface moisture and water absorptions of aggregates as per IS:2386(part 3) and the final concrete mix proportion per cubic meter obtained for OPC and PPC based concrete mixes are determined and calculated.

The mix proportioning of concrete was done by selecting M30 grade of concrete and water cement ratio of 0.45 for both OPC and PPC based concrete mixes in order to study and compare concrete strength properties while using different binding materials and curing methods . The concrete mix proportion per cubic meter used for OPC and OPC based concrete mixes were determined and calculated as shown below.

3.3.1.1 Mix proportion for 1 m^3 concrete

1. Data Required for Concrete Mix Design of OPC mix

i) Concrete mix Design Stipulations

a) Characteristic compressive strength required at 28 days: 30N/mm^2 **(**M30Grade)

b) Type of cement used: OPC 53 Grade (confirming to IS: 12269)

c) Nominal maximum size of aggregate   : 20 mm

d) Shape of coarse aggregates   : Angular

e) Degree of workability required at site   : 90-100 mm (slump)

f) Degree of quality control: Good

g) Type of exposure the structure will be subjected to (as defined in IS: 456) :Severe

ii) Test data of material (to be determined in the laboratory)

The following materials are to be tested in the laboratory and results are to be ascertained for the concrete mix design for OPC mix.

a) Specific Gravity of Cement: 3.15

b) Chemical admixture   : Super plasticizer confirming to IS: 9103

c) Specific gravity

i) Specific gravity of Fine Aggregate (sand)   : 2.58

ii) Specific gravity of Coarse Aggregate   :2.70

d) Water Absorption

i) Fine Aggregate   : 1%

ii) Coarse Aggregate : 0.2%

e) Free (surface) moisture

i) Coarse Aggregate : Nil

ii) Fine Aggregate : Nil

f) Fine aggregate falls into : Zone-II

iii) Procedure for Concrete Mix Design of M30 Concrete

Step 1.Determination ofTarget mean strength of concrete

$f_{ck\,1} = f_{ck} + (1.65 \times s)$

$= 30 + (1.65 \times 5.0)$

$= 38.25\ N/mm^2$.

$f_{ck\,1}$= Target average compressive strength at 28 days,

f_{ck}= Characteristic compressive strength at 28 days,

s = Standard deviation

From table1 of IS:10262-2009, s =5 N/mm^2

Step 2. Selection of water cement ratio:

From table 5 of IS:456-2000 maximum, W/C ratio =0.45

(For Severe exposure condition)

Step 3. Selection of water content:

From table 2 of IS:10262-2009 for 20mm nominal maximum size aggregate and fine aggregate conforming to grading zone 2 and for 25-50mm slump range maximum water content per cubic meter of concrete=186 kg.

Estimated water content for 90-100 mm slump => 186 + (6/100) x 186 = 197 Kg/m^3.

As the superplasticizer is used the water content can be reduced up to 20 percent and above as per IS 1026:2009. Based on trials with superplasticizer water content reduction of 10 % has been achieved. Hence the arrived water content= 197- (197 x10/100) = 177 litres.

Step 4. Calculation of cement content:

W/C ratio = 0.45,thencement content = 177/0.45

= 393 kg/m^3

From table 5 of IS:456-2000 minimum cement for Severe exposure condition is 320 kg/m^3. Therefore 393kg/m^3 > 320 kg/m^3,Hence ok

Step 5. Proportions of volume of coarse aggregate and fine aggregate content

- From table 3 of IS10262-2009 , volume of coarse aggregate corresponding to 20 mm nominal size of aggregate and zone of fine aggregate of 2, for W/C ratio of 0.5**,** the volume of coarse aggregate is0.62.(As the W/C is lowed by 0.05 from 0.5 to 0.45,the proportion of volume of CA is increased by 0.01).
- Hence, Volume of coarse aggregate per unit volume of total aggregate = 0.62+0.01=0.63
- Volume of fine aggregate = 1 – 0.63 = 0.37

Step 6. Mix calculation

The mix calculation per unit volume of concrete for OPC of specific gravity of 3.15 is determined as below:

a) Volume of concrete = 1 m^3

b) Volume of cement= (mass / specific gravity) x (1/ 1000)

= (393/ 3.15) x (1/ 1000)

= 0.124 m^3

c) Volume of water = (mass / specific gravity) x (1/ 1000)

= (177 / 1) x (1 /1000)

= 0.177 m^3

d) Volume of chemical admixture (superplasticizer @ 2.0% by mass of cementitious materials. Based on trials with superplasticizer, 1.5% by mass of cementitious materials has been achieved).Here specific gravity of superplasticizer is 1.20 at 30^{0}c.

Vol= (Mass of chemical admixture/specific gravity of admixture) x (1/1000)

= (5.895/1.20) x (1/1000)

= 0.00491 m3

e) Volume of all aggregates = 1- (b +c+d)

= 1 – (0.124 + 0.177 +0.00491)

= 0.694 m^3

f) Mass of coarse aggregates = volume of aggregate x proportion of aggregate x specific gravity of aggregate x1000.

= 0.694 x 0.63 x 2.70 x 1000

= 1180 kg

g) Mass of fine aggregate = volume of aggregate x proportion of aggregate x specific gravity of aggregate x 1000

= 0.694 x 0.37x 2.58 x 1000

= 663 kg

Table3.9 Concrete mix proportion for OPC mix (per m^3)

W/C ratio	**Water in litre**	**Cement in (kg)**	**Fine Aggregate (kg)**	**Coarse Aggregate (kg)**
0.45	177	393	663	1180
		1	1.69	3.0

2. Data Required for Concrete Mix Design of PPC mix

i) Concrete mix Design Stipulations

a) Characteristic compressive strength required at 28 days: 30N/mm^2 **(**M30Grade)

b) Type of cement used: PPC (confirming toIS: 1489-1991)

c) Nominal maximum size of aggregate : 20 mm

d) Shape of coarse aggregates : Angular

e) Degree of workability required at site : 90-100 mm (slump)

f) Degree of quality control: Good

g) Type of exposure the structure will be subjected to (as defined in IS: 456) :Severe

ii) Test data of material (to be determined in the laboratory)

The following materials are to be tested in the laboratory and results are to be ascertained for the concrete mix design for PPC mix.

a) Specific Gravity of Cement: 2.85

b) Chemical admixture : Super plasticizer confirming to IS: 9103

c) Specific gravity

i) Specific gravity of Fine Aggregate (sand) : 2.58

ii) Specific gravity of Coarse Aggregate :2.70

d) Water Absorption

i) Fine Aggregate : 1%

ii) Coarse Aggregate : 0.2%

e) Free (surface) moisture

i) Coarse Aggregate : Nil

ii) Fine Aggregate : Nil

f) Fine aggregate falls into : Zone-II

iii) Procedure for Concrete Mix Design of M30 Concrete

Step 1.Determination ofTarget mean strength of concrete

fck 1= fck + (1.65 x S)

= 30 + (1.65 x 5.0)

=**38.25 N/mm^2.**

fck 1= Target average compressive strength at 28 days,

fck= Characteristic compressive strength at 28 days,

s = Standard deviation

From table1 of IS10262-2009, S=5 N/mm^2

Step 2. Selection of water cement ratio:

From table 5 of IS456-2000 maximum, W/C ratio =0.45

(For Severe exposure condition)

Step 3. Selection of water content:

From table 2 of IS10262-2009 for 20mm nominal maximum size aggregate and fine aggregate conforming to grading zone 2 and for 25-50mm slump range maximum water content per cubic meter of concrete=186 kg.

Estimated water content for 90-100 mm slump => 186 + (6/100) x 186 = 197 Kg/m^3.

As the superplasticizer is used the water content can be reduced up to 20 percent and above as per IS 1026:2009.

Based on trials with superplasticizer water content reduction of 10 % has been achieved. Hence the arrived water content= 197- (197 x10/100) = 177 litres.

Step 4. Calculation of cement content:

W/C ratio = 0.45,thencement content = 177/0.45

= 393 kg/m^3

From table 5 of IS456-2000 minimum cement for Severe exposure condition is 320Kg/m^3. Therefore 393Kg/m^3 > 320Kg/m^3,Hence ok

Step 5. Proportions of volume of coarse aggregate and fine aggregate content

- From table 3 of IS10262-2009 , volume of coarse aggregate corresponding to 20 mm nominal size of aggregate and zone of fine aggregate of 2, for W/C ratio of 0.5**,** the volume of coarse aggregate is0.62.(As the W/C is lowed by 0.05 from 0.5 to 0.45,the proportion of volume of CA is increased by 0.01).
- Hence, Volume of coarse aggregate per unit volume of total aggregate = 0.62+0.01=0.63
- Volume of fine aggregate = 1 – 0.63 = 0.37

Step 6. Mix calculation

The mix calculation per unit volume of concrete for PPC of specific gravity of 2.85 is determined as below:

a) Volume of concrete= 1 m^3

b) Volume of cement = (mass / specific gravity) x (1/ 1000)

= (393/ 2.85) x (1/ 1000)

= 0.137 m^3

c) Volume of water = (mass / specific gravity) x (1/ 1000)

= (177 / 1) x (1 /1000)

= 0.177 m^3

= 0.177 m^3

d) Volume of chemical admixture (superplasticizer @ 2.0 % by mass of cementitious materials) Here specific gravity of superplasticizer is 1.20 at 30^0c.

Vol= (Mass of chemical admixture/specific gravity of admixture) x (1/1000)

=(7.86/1.20) x (1/1000)

= 0.00655m3

e) Volume of all aggregates = 1- (b +c)

= 1 – (0.137 + 0.177+ 0.00655)

= 0.679 m^3

f) Mass of coarse aggregates = volume of aggregate x proportion of aggregate x specific gravity of aggregate x1000.

= 0.679 x 0.63 x 2.70 x 1000

= 1155 kg

g) Mass of fine aggregate = volume of aggregate x proportion of aggregate x specific gravity of aggregate x 1000

= 0.679 x 0.37 x 2.58 x 1000 = 648 kg

Table3.10 Concrete mix proportion for PPC mix (per m^3)

W/C ratio	**Water in litre**	**Cement (kg)**	**Fine Aggregate (kg)**	**Coarse Aggregate (kg)**
0.45	177	393	648	1155
		1	1.65	2.94

3.4 TESTS ONFRESH CONCRETE

3.4.1 Workability of fresh concrete for OPC and PPC mixes

Fresh concrete is the concrete which is mixed freshly and can be moulded into any shape. Fresh concrete should be workable to ease working and casting into the required shape. Fresh properties of concrete are tested through workability of concrete. Workability is the ease of being able to work concrete into different parts of the formwork. Concrete mixes should be tested for workability as workability decides the choice of equipment to be used for handling, placing and compacting concrete.

Workability is defined as the amount of work necessary to achieve full compaction. It is the ease with which concrete can be placed and degree to which it can resist segregation. It is also given a new definition which includes all the essential properties of the concrete in plastic condition i.e. mixability, transportability, modulability and ease compaction.

Some of the important factors that affect the workability of concrete are:

- Relative quantities of paste and aggregate.
- Plasticity of the paste itself.
- Maximum size and grading of aggregate
- Shape and surface characteristics of aggregate particle.

Consistency of the concrete is an important component of workability and refers in away to the wetness of concrete. However it must be assumed that the wetter the mix more workable it is. If a mix is too wet, segregation may occur resulting in honeycombing, excessive bleeding and sand streaking on the formed surfaces. On the other hand if the mix is too dry it may be difficult to place and compact, segregation may occur because of lack of cohesiveness and plasticity of the plastic state of concrete. The workability of concrete connected with the physical quantity is correlated by slump test, compaction factor test and Vee-Bee test. Depending on the slump values of concrete, it can be classified into different categories as per IS: 1199-1959.

3.4.2 Slump test of the concrete forboth OPC and PPC mixes

The slump test is commonly used to measure workability of concrete. It is the easiest method that can be used both in laboratory and site with less effort. Slump test is performed using a slump cone, scale and a tamping rod. Slump is used a parameter to asses workability through slump test.

In this research project work,theconcrete slump test was conducted for both OPC and PPC concrete mixes.The concrete was poured into slump cone which was lubricated with oil, concrete was poured in three layers and each layer was compacted using tamping rod for 25 times. Extra concrete was struck off with trowel and any spill out slump cone was cleaned.

Slump cone was then lifted slowly and vertically to let concrete fall on gravity. The subsidence of concrete was then measured which gives slump values of the concrete. The slump cone test is shown in figure below and cone has the following dimensions:

- Bottom Diameter: 200mm
- Top Diameter: 100 mm
- Height of the cone: 300 mm

a) OPC Concrete mix b) PPC Concrete mix

Figure3.6 Slump cone test

3.5 CASTING OF CONCRETE SPECIMENS

3.5.1 Mixing

Before starting the mixing for the required quantity of materials for concrete, concrete ingredient materials are weighed accurately as per the mix proportioning done before. At first, the natural fine aggregates and cement are added into the concrete mixer, these materials dry mixed for a minute in the mixer followed by addition of coarse aggregate and again dry mixed for a minute. Then finally calculated amount of water is added with superplasticizer into the mixer and again mixed for 2 minutes. The concrete specimens for both OPC and PPC mixes are cast separately to consider their fresh properties and the strength characteristics of concrete.

3.5.2 Casting of the specimens

The specimens were cast for testing the mechanical properties of concrete such as compressive strength, split strength and flexural strength, then concrete water absorption. For compressive strength test, cubes of size 150mm×150mm×150mm were used. These cubes were filled with flesh concrete and compacted by using vibrating table. A total of 90 cubes were cast from all concrete mixes.

A bout 33 cubes were cast for OPC and 33 cubes for PPC concrete mixes and cement compressive strength for both types of binders (OPC and PPC), then for concrete water absorption, 24 cubes were cast for both OPC and PPC concrete mixes ie 12cubes for OPC mixes and 12 cubes for PPC mixes. For split tensile strength, cylinders of the size 150 diameter and 300 mm height were cast. A total of 12 cylinders were cast from all concrete mixes. About 6 cylinders were cast for OPC and 6 cylinders for PPC concrete mixes. Similarly for flexural strength beams of size 100mm×100mm×500mm were cast. A total of 12 beams were cast from all concrete mixes.A bout 6beams were cast for OPC and 6 beams for PPC concrete mixes. The specimens were demoulded from the moulds carefully after 24 hours of casting without any damage to the specimens.

Figure3.7 Casting of the concrete specimens

3.5.3 Demoulding of the concrete specimens

The test specimens were removed from the moulds after 24hrs (after attaining the initial strength), while demoulding the specimens care was taken such that there will not be any damage to the concrete specimens.

Figure3.8 Demoulding of the concrete specimens

3.5.4 Curing of the concrete specimens

The concrete specimens were demoulded from the moulds and then immediately curing of the concrete specimens was done using the curing tanks in civil engineering laboratory ofNITK (India) for conventional curing and others specimens were placed out of water curing tank for external self curingfor the application of curing compound. After demoulding, the specimens reserved for conventional curing concrete were kept in water until the days of testing 3, 7, 28 and 56 days and those reserved for external self curing concrete, curing compound was applied on their external surfaces after demoulding and also tested at the same time interval as shown above.

Figure3.9 Curing of concrete specimens by conventional curing method

Figure3.10 Curing of concrete specimens by external self curing method

3.6 MECHANICAL PROPERTIES OF CONCRETE

Details of the standard specimens for OPC and PPC mixes

Tests were conducted on standard cubes specimens of 150 x 150 x 150 mm size, cylinders of 150 x300mm sizeandbeams of 100 × 100 × 500 mm size, which were cast in NITK (India) laboratory for testing. The test specimens were marked, removed from the moulds and immediately submerged in clean fresh water for normal curing. For external self curing concrete, specimens were cured by the application curing compound (Concure WB from Fosroc India Ltd) after removed from the moulds. Compression Testing Machine was used to conduct the test. From each type of curing condition 3, 7, 28 and 56 days compressive strength results were obtained as per IS:516-1959.

In the present investigation, three types of specimens namely cubes, cylinders and beams were cast. Cubes were used for compressive strength test and water absorption, cylinders for split tensile strength test and beams for flexural strength test. The details of the standard specimens tests used in the investigation are shown bellow.

3.6.1 Compressive strength test of hardened concrete for OPC and PPC mixes.

Strength of concrete is the most important property of concrete, although other characteristic may also be critical and cannot be neglected. Strength is an important indicator of quality because strength is directly related to the structure of hardened cement pasted. Even though strength is not a directed measure of durability or dimensional stability, it has a strong relationship with the water to cement ratio of the concrete which in turn influences durability, dimensional stability and other properties of hardened concrete.

The properties of constituent materials such as the quality of aggregates, the quality of cement paste and the bond between aggregates and cement paste influence the strength of concrete. The testing of the cubes was done using compression testing machine. The compression test was conducted on cubes of size 150 x 150 x 150 mm for both OPC and PPC mixes for 3,7,28 and 56 days of curing respectively as conforming to IS:516-1959.

The testing of the cubes was done in a 200T capacity compression testing machine and the load was applied without shock at a rate of 140kg/cm^2/min. Cubes testing is shown below in the figure3.11 and the compressive strength of concrete was determined with the following formula.

- **Compressive Strength of concrete**= Applied load /Cross-section Area of the Specimen(cube)

3.6.1.1 Determination of compressive strength for conventionally and external self curing concrete.

The specimens were removed from the curing tank and its surfaces are cleaned with cotton waste. Three cubes specimens of 150 x 150x150 mm were tested and the mean value was computed for the required age, then the average result for compressive strength was calculated. A total of 48 cubes are used to determine the compressive strength of concrete for both OPC and PPC mixes. For external self curing concrete, the curing compound concure WB was applied on the surface of concrete specimen cubes after demoulding to provide external self curing of concrete. The compound was applied in three coats by brushing on the surface of concrete cubes and allowed to set on external surfaces of concrete specimens. The specimens were tested for 3, 7, 28 and 56 days in order to get compressive strength for external self curing concrete. The average of three specimens tested for each curing techniques helps to determine the average results of compressive strength tests for conventional and external self curing concrete form both OPC and PPC mixes.

Figure3.11 Testing of cubes for compressive strength of concrete

3.6.2 Split tensile strength test of hardened concrete for OPC and PPC mixes

The split tensile strength test is well-known as indirect tests used for determining the tensile strength of concrete sometimes referred to as split tensile strength of concrete. The test consists of applying a compressive line load along with the opposite generators of a concrete cylinder generally of size 150mm diameter and 300mm height placed with its axis horizontal between the compressive plates. Three cylinders from each batch of concrete mix are cast and cured for 28 days in order to determine split tensile strength of concrete for both conventional and self curing concrete. The split tensile test was conducted for 28 days. Testing to determine split tensile strength of all specimens was carried out as per IS: 516-1959.

3.6.2.1 Determination of split tensile strength test for conventionally and external self cured concrete

The average of three cylindrical specimens for concrete was obtained to determine the split tensile strength of concrete. The determination of split tensile strength for conventional and external self curing concrete was conducted on a total number of 12 cylinders of size 150×300mm to determine the split tensile strength of concrete for both OPC and PPC mixes. For external self curing concrete, curing compound (concure WB) was applied on the external surfaces of cylindrical specimens after demoulding and allowed to set properly. The test was conducted for 28 days and the averageresultof split tensile strength of concrete for conventional and external self curing concrete was calculated.

The tests were performed using a Compression Testing Machine, three specimens were tested and the mean value was computed. The magnitude of this tensile stress f_{st}(acting in a direction perpendicular to the line of fracture of applied loading) is given by the following formula and cylindrical specimen in testing machine is shown below.

- **Resultant Split Tensile Strength (f_{st}) =2P/πDL**

Where: **P**= Load at failure (maximum applied load)

L=Length of the cylinder

D=Diameter of cylinder

Figure3.12 Testing of concrete split tensile strength

3.6.3 Flexural strength test of concrete for both OPC and PPC mixes

Flexural strength of concrete is defined as the ability of concrete to resist deformation under load. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 6 x 6 inch (150 x 150mm) concrete beams with a span length at least three times the depth. The flexural strength is expressed as modulus of rupture in MPa and is determined by standard test methods ASTM C 78 (third-point loading) or ASTM C 293 (center-point loading).

This test method covers the determination of the flexural strength of concrete by the use of a simple beam with third-point loading. A simply supported concrete prism is loaded by two point loads placed at third points along the span. The load is monotonically increased until flexural failure occurs. Based on the peak load, the peak flexural stress within the prism is calculated. ASTM C78formed the basis for the development of this procedure and this method is commonly referred to as the modulus of rupture. The average of three beams from each batch of concrete mix is cast and cured for 28 days in order to determine the flexural strength of concrete for conventional and self curing concrete for both OPC and PPC mixes.

3.6.3.1 Determination of flexural strength test for conventionally and external self cured concrete

The standard beam moulds for producing hardened concrete specimens of nonabsorbent and rigid material were used. The standard beam test or modulus of rupture carried out on the beam of size 100 mm × 100 mm × 500 mm.

The beam should be tested on a span of 400mm for 100mm specimen by applying two equal loads placed at third points. To get these loads, a central point load is applied on a beam supported on steel rollers placed at third point. The rate of loading shall be1.8kN/minute for 100mm specimens, the load should be increased until the beam failed. A total of 12 beams specimens are cast and cured for 28days in order to determine flexural strength of concrete. Testing to determine flexural strength of all specimens was carried out as per IS: 516-1959.

The loading and specimen support system shall be capable of applying third-point loading to the specimen without eccentricity or torque. The fixtures normally used for flexural testing are suitable with the qualification that supporting rollers shall be able to rotate about their axes and shall not be placed in grooves or have other restraints that prevent their free rotation. The determination of flexural strength for external self curing concrete and convention curing concrete was done after demoulding and proper curing as required. Three beams were tested for 28 days and the averageresultfor flexural strength of concrete was calculated. The flexural strength test for both conventional and external self curing concrete was conducted on all beams specimens from both OPC and PPC mixes. The arrangement of the test is shown in the figure3.13 bellow.

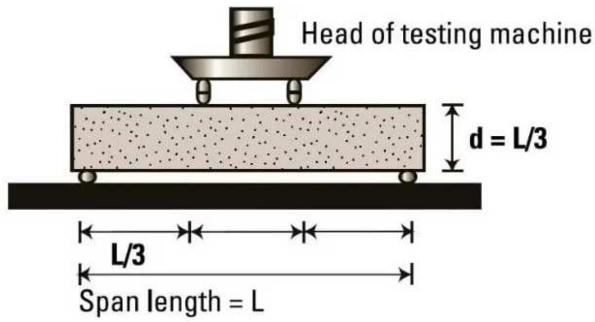


Figure3.13 Testing of concrete flexural strength

If '**a'**is the distance between the line of fracture and the nearest support. Then for finding the modulus of rupture, these cases should be considered.

- When **a**>133mm for 100mm specimen or "a" is greater than 200 mm for 150 mm specimen, calculate the modulus of rupture to the nearest support as:

R= PL/bd^2

Where:

R = Modulus of rupture or flexural Strength

P= Maximum applied load indicated by the test machine (applied to the beam)

L = Length of the span on which the specimen was supported (Span length in cm)

b = Average width of the specimen as oriented for testing.

d = Average depth of the specimen as oriented for testing.

- When 110mm<**a** <133mm for 100 mm specimen or "a" is less than 200 mm but greater than 170 mm for 150mm specimen, the formula below is used. In the case "a" is less than 110 mm (a <110 mm) the result should be discarded. If the fracture initiates in the tension surface outside of the middle third of the span length by not more than 5 percent of the span length, calculate the modulus of rupture to the nearest support as:

R=3Pa/bd^2

Where: **R** =Flexural Strength or Modulus of Repture

a = Average distance between the line of fracture and the nearest support measured on the tension surface of the beam.

3.6.3.2 Scanning Electron Microscopy (SEM) for both OPC and PPC concrete mixes

The scanning electron microscope (SEM) is a powerful technique in the examination of materials. It is used widely in metallurgy, geology, biology, engineering and medicine, to name just a few. The user can obtain high magnification images, with a good depth of field and can also analyse individual crystals or other features.A high-resolution SEM image can show detail down to 25 Angstroms, or better. When used in conjunction with the closely-related technique of energy-dispersive X-ray microanalysis (EDX, EDS, EDAX), the composition of individual crystals or features can be determined.SEM is one of the most versatile instruments available for the examination and analysis of microstructural characteristics of solid objects.After Compressive testing for 56 days was finished, the cube samples are crushed and the hydrated cement was collected from the innermost core of the concrete cube sample for both OPC and PPC mixes and theSEM test was carried out in NITK Scanning Electron Microscope laboratory.

3.7 CONCRETE WATER ABSORPTION FOR CONVENTIONAL AND EXTERNAL SELF CURING CONCRETE

3.7.1 Concrete water absorption

Concrete water absorption is the ability of concrete to retain a certain amount of liquid (water) in their air spaces, which is a key property when it comes to the resistance of the concrete in the environment. Concrete water absorption is measured by measuring the increase in mass as a percentage of dry mass. It can be seen that surface water absorption is higher than internal water absorption for all the specimens; this is due to the rapid loss of water at the cover concrete during curing. Concrete water absorption is used to determine the amount of water absorbed under specified conditions. Factors affecting water absorption include type of plastic, additives used, temperature and length of exposure.

The present research project work, percentage concrete water absorption was determined in details for 53 grade OPC and PPC mixes after 28 days. This test was conducted on concrete specimens (cubes) after the minimum required time for concrete curing process and it was done to determine the amount of water absorbed under specified conditions for both conventional and external self curing concrete.

The total number of 24 specimens of size 150mm x 150mm x 150 mm cubes were cast and cured in water tank, others with the curing compound for 28days to determine concrete water absorption for both conventional and external self curing concrete. The oven-dry mass and the saturated mass (using immersion in water) of samples for each specimen for both conventional and external self curing concrete were obtained to determine percentage of concrete water absorption. The average weights of three specimens were measured and recorded to calculated percentage of concrete water absorption.

3.7.2 Determination of concrete water absorption for OPC and PPC mixes

Concrete water absorption test by ASTM C642 method.

ASTM C642 was used in this project work and is one of the laboratory test method to determine water absorption of concrete. ASTM C642 determines the total amount of water absorption using two saturation methods. According to this method, there is no shape limitation for testing concrete specimens other than each sample volume is not less than 350 cm^3 (approximately equal to 800 g). After casting concrete specimens and curing process for 28days, the average weights of specimens are taken and recorded to calculated concrete water absorption as described below.

In the first step, the oven-dry mass of each specimen should be obtained by placing the specimen in an oven at a temperature of 100 to 110℃ not less than 24 hours, after removing each specimen from the oven, allow it to cool in dry air to the temperature of 20 to 25 °C and determine the mass. The specimen was comparatively dry when its mass was first determined and the second mass closely agrees with the first, consider it dry. If the specimen was wet when its mass was first determined, place it in the oven for a second drying treatment of 24hours and again determine the mass. If the third value checks the second, consider the specimen dry. In case of any doubt, redry the specimen for 24hours periods until check values of mass are obtained. If the difference between values obtained from two successive values of mass exceeds 0.5 % of the lesser value, return the specimens to the oven for an additional 24hours drying period, and repeat the procedure until the difference between any two successive values is less than 0.5 % of the lowest value obtained. The weight was noted as the dry weight W1of the specimen. Later, the saturated mass (using immersion) of samples will be determined by immersing them in water at approximately 21˚ C for not less than 48 hours and the two successive measurements of mass of the surface-dried samples at intervals of 24 hours indicate constant massie indicate the increase in mass of less than 0.5 % of the larger value. Surface dry the specimen by removing surface moisture with a towel and determine the mass, Then this weight is noted as the wet weight W2 of the specimen. The second method obtains the saturated mass by using immersion in boiling water. The specimen samples processed as described above in a suitable receptacle are covered by tap water and boiled or the specimen was kept in hot water at 85°c for 5 hours. After that, they will be allowed to cool to a final temperature of 20 to 25˚C for a period of not less than 14 hours, remove the surface moisture with a towel and determine the mass of the specimen (ASTM C642), Then this weight was noted as weight W3 of the of the specimen.

In this research project work, the cubes specimens of 150mm x 150mm x 150 mm were used for both OPC and PPC concrete mixes. After casting and demoulding a total number of 12 cube specimens were cured in water tank for conventional curing concrete and also a total number of 12 specimens were cured by the application of curing compound (Concure WB) for external self cured concrete for 28 days and after were placed in the oven. The oven-dry mass of each specimen was obtained and noted as the dry weight W1 of the specimen. The saturated mass (using immersion of cube specimens in water) of samples was determined and noted as the wet weight W2 of the specimen. Finally, the saturated mass by using immersion in boiling water was obtained and the weight was noted as weight W3 of the specimen. The condition and the procedure for concrete water absorption test were considered and described careful step by step as shown clearly above as per ASTM C642 method. The average weights of three specimens for OPC and PPC mixes within different curing conditions were then taken and recorded to determine percentage of concrete water absorption.

Two different values of the concrete samples' capability of water absorption will be calculated as follows and the average weight of specimen was determined by measuring the weight of three specimens for both OPCandPPCconcretemixes with the following formula.

- Concrete water absorption after immersion,% =[(W2-W1)/W1] ×100
- Concrete water absorption after immersion and boiling,%

  = [(W3-W1)/W1] ×100

Where:W 1: Mass of oven-dried sample (in gm), W 2: Mass of surface-dry sample in air after immersion (in gm), W 3: Mass of surface-dry sample in air after immersion and boiling (in gm).

Figure3.14 Oven-dry mass of samples for concrete water absorption

Figure3.15 Saturated mass of samples for concrete water absorption

Figure3.16 Saturated mass by using immersion in boiling water at 85^{oc}

CHAPTER 04

RESULTS AND DISCUSSION

4.1 GENERAL

In this chapter, observations and the results from the tests performed for normal and external self curing concrete are given in details. The laboratory investigation consisted of the tests for both hardened and fresh concrete was determined, the fresh property of concrete through slump test was tested using slump cone in order to ensure reasonable workability in the plastic state and the test results on mechanical properties of concrete such as compressive strength, split tensile strength and flexural strength of concrete and concrete water absorption for both OPC and PPC concrete mixes using conventional and external self curing method were determined and presented in this section.

4.2 FRESH PROPERTIES OF OPC AND PPC CONCRETE MIXES

Fresh properties of concrete are one of the major criteria of concrete quality in the field of civil engineering and it is generally worked out in terms of workability of concrete. For determining the flow ability for OPC and PPC concrete mixes, slump test was conducted in the laboratory for both mixes. Fresh property of concrete such as slump test results has been made as shown below.

4.2.1 Slump Test

The slump values of different binding materials such as OPC and PPC based concrete mixes were determined and calculated. It was observed that the average slump was 90 mm for OPC and 95mm for PPC concrete mixes, which are well within the design slump limit.

4.3 COMPRESSIVE STRENGTH TEST RESULTS FOR CEMENT PASTE

Compressive strength testing for all specimens was carried out as per IS: 516-1959. The load was applied without shock at a rate of 140Kg/cm^2/min. The maximum load resisted divided by cross sectional area of specimen, gives the compressive strength.

The compressive strengths of cement paste were determined for 3, 7 and 28 days. A set of three cubes specimens were taken and tested to get average results as tabulated and interpreted below. For the compressive strength of cement paste (OPC and PPC), the size of the specimen was 50mm×50mm×50mm. The total number of eighteen cubes specimens for both OPC and PPC paste were used.

4.3.1 Result of Compressive strength test for both OPC and PPC cementpaste

For 3, 7 and 28 days compressive strength results of OPC and PPC cement are given in the tables and figures below.

i) Results of compressive strength test for Ordinary Portland cement (OPC)

Table4.1 Average Compressive Strength of OPC Cement for 3,7and 28 days

SI.No	**Weight of the cube (in gm)**	**Failure Load (KN)**	**Compressive strength (N/mm^2)**	**Average compressive strength(N/mm^2)**	**Days**
1.	270	62	24.80	25.87	3 days
	272	67	26.80		
	278	65	26.00		
2.	268	70	28.00	28.93	7days
	278	73	29.20		
	278	74	29.60		
3.	276	88	35.20	36.53	28 days
	276	90	36.00		
	284	96	38.40		

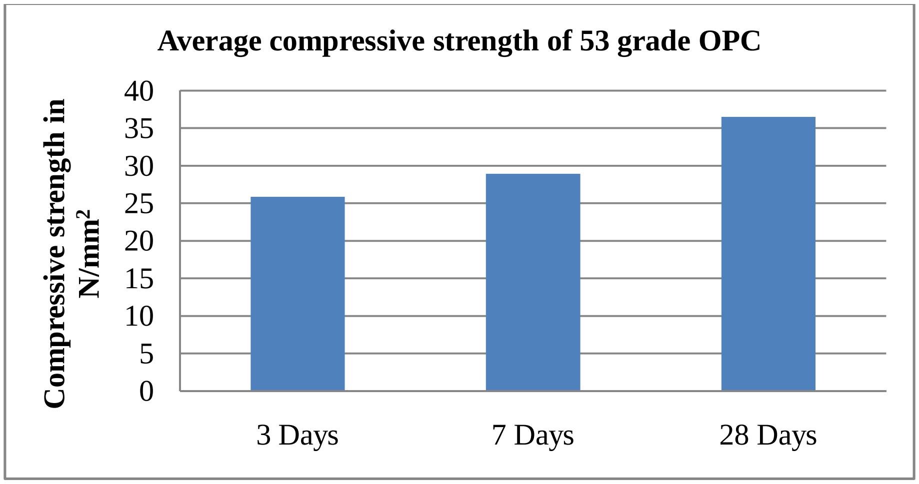


Figure4.1 Compressive strength of ordinary Portland cement

ii) Results of compressive strength test for Portland Pozzolona cement(PPC)

Table4.2 Average Compressive Strength of Cement (PPC) for 3,7and 28 days

SI.No	Weight of the cube	Failure Load (KN)	Compressive strength (N/mm^2)	Average compressive strength(N/mm^2)	Days
1.	244	56	22.40	21.06	3 days
	258	52	20.80		
	262	50	20.00		
2.	254	65	26.00	26.26	7days
	260	63	25.20		
	264	69	27.60		
3.	260	75	30.00	31.20	28 days
	272	79	31.60		
	266	80	32.00		

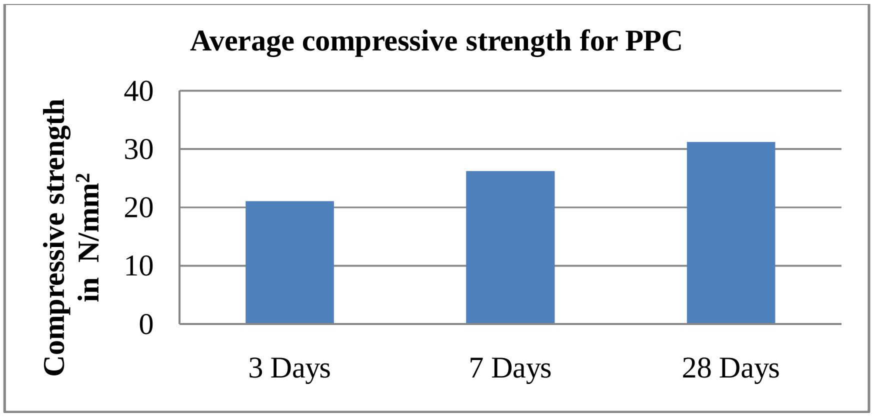


Figure4.2 Compressive strength for Portland pozzolana cement

ii) Comparison of cement compressive strength between Ordinary Portland cement (OPC) **and Portland Pozzolona cement (PPC).**

For 3, 7, 28 days compressive strength test for OPC and PPC cement paste**.** The results of compressive strength for OPC cement were observed to be greater than that of PPC cement at all 3, 7 and 28 days by normal curing as shown in the figure below.

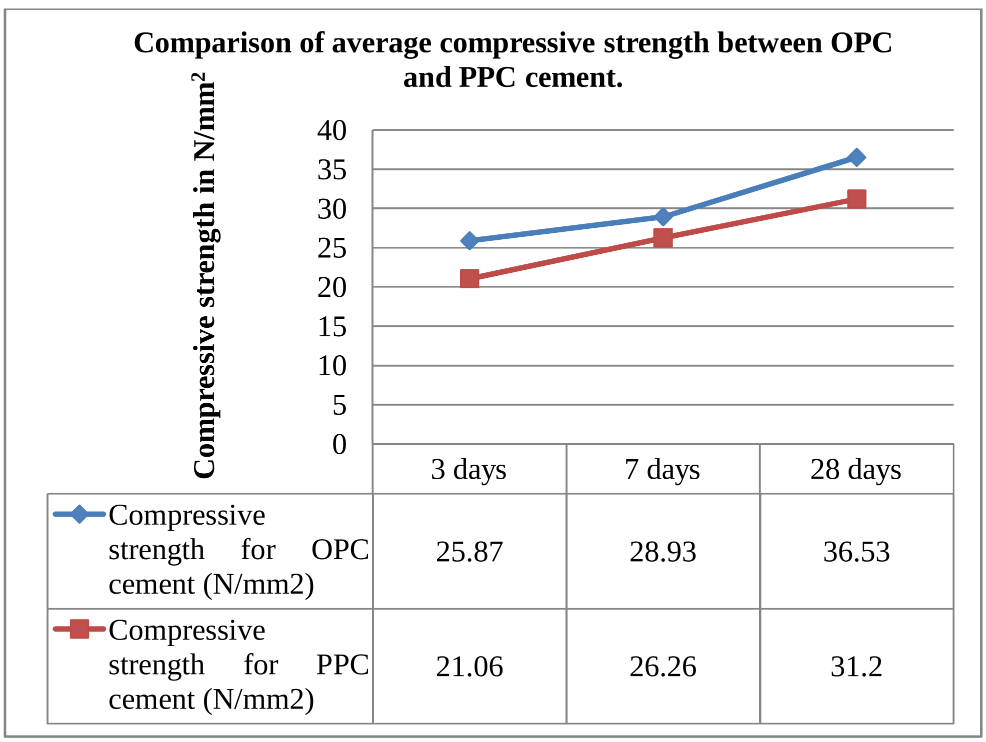


Figure4.3 Comparison of compressive strength for OPC and PPC cement paste

4.4 COMPRESSIVE STRENGTH TEST RESULTS FOR CONCRETE

Compressive strength testing for all specimens was carried out as per IS: 516-1959. The load was applied without shock at a rate of 140 $kg/cm^2/min$. The maximum load resisted divided by cross sectional area of the specimen, gives the compressive strength of concrete. A set of three cubes specimens were tested to get average results on compressive strength of concrete from the tests done. The compressive strengths were determined for 3, 7, 28 and 56 days. The concrete specimens (cubes) of size 150 mm ×150mm×150 mm were taken from both OPC and PPC mixes by conventional and self curing concrete and the results were tabulated and presented below. The total number of forty eight cubes from both OPC and PPC concrete mixes were used.

4.4.1 Results of compressive strength for normal and external self curing concrete for both OPC and PPC mixes

For 3, 7, 28 and 56 days compressive strength results of concrete for OPC and PPC concrete specimens are given in the tables and figures below. The results in compressive strength of normal and external self curing concrete were obtained to determine the comparison of concrete strength while using different binding materials and curing methods.

4.4.1.1 Compressive strength of concrete for OPC mix

The tests were performed by placing a concrete specimen in Compression Testing Machine. Three specimens were tested, the mean value of compressive strength was computed and the results were determined for3, 7, 28 and 56 days.

i) Results on Compressive strength test for conventionally cured concrete

Table4.3 Average compressive strength of conventional cured concrete for OPC mix

SI.No	Weight of the cubes (kg)	Failure Loads (kN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)	Days
1.	8.596	540	24.00	25.47	3 days
	8.494	580	25.77		
	8.545	600	26.66		
2.	8.330	715	31.78	32.37	7days
	8.588	750	33.34		
	8.356	720	32.00		
3.	8.428	980	43.56	42.52	28 days
	8.568	960	42.67		
	8.398	930	41.33		
4.	8.478	1250	55.55	54.36	56 days
	8.460	1220	54.22		
	8.392	1200	53.33		

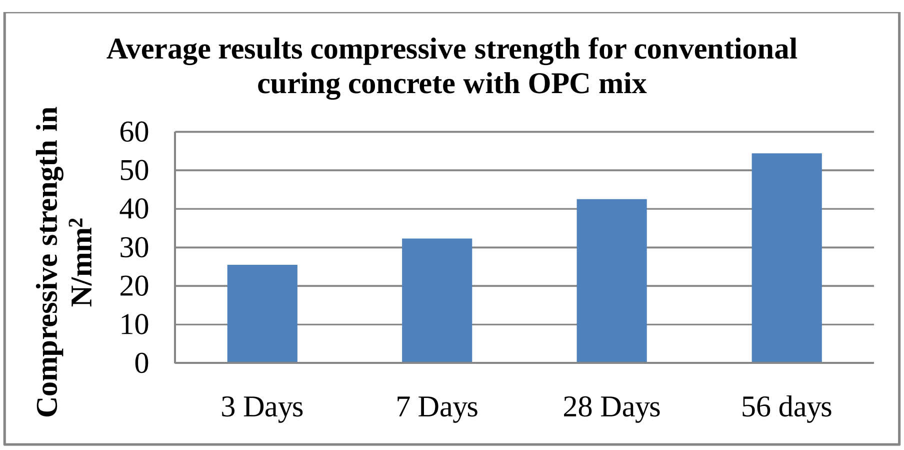


Figure4.4 Compressive strength for conventionally cured concrete for OPC mix

ii) Results on Compressive strength test for external self cured concrete

Table4.4 Average compressive strength of external self cured concrete for OPC mix

SI.No	Weight of the cubes (kg)	Failure Load (kN)	Compressive strength (N/mm^2)	Average compressive strength(N/mm^2)	Days
1.	8.327	515	22.89	23.19	3 days
	8.292	530	23.55		
	8.362	520	23.12		
2.	8.428	620	27.55	30.95	7days
	8.242	740	32.88		
	8.160	730	32.44		
3.	8.144	890	39.55	38.85	28 days
	8.430	860	38.22		
	8.158	850	37.78		
4.	8.570	1100	48.88	46.66	56 days
	8.406	1050	46.66		
	8.374	1000	44.44		

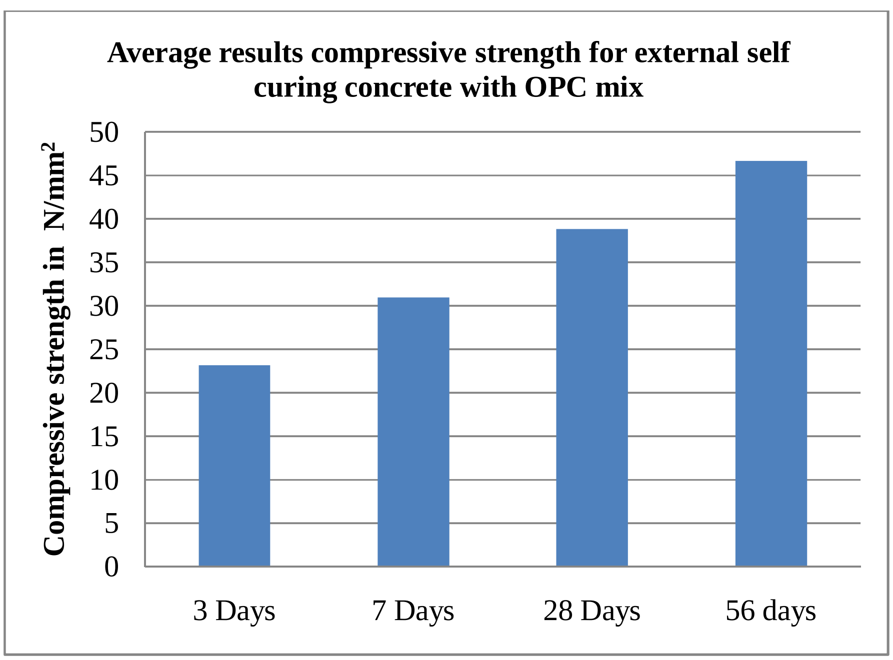
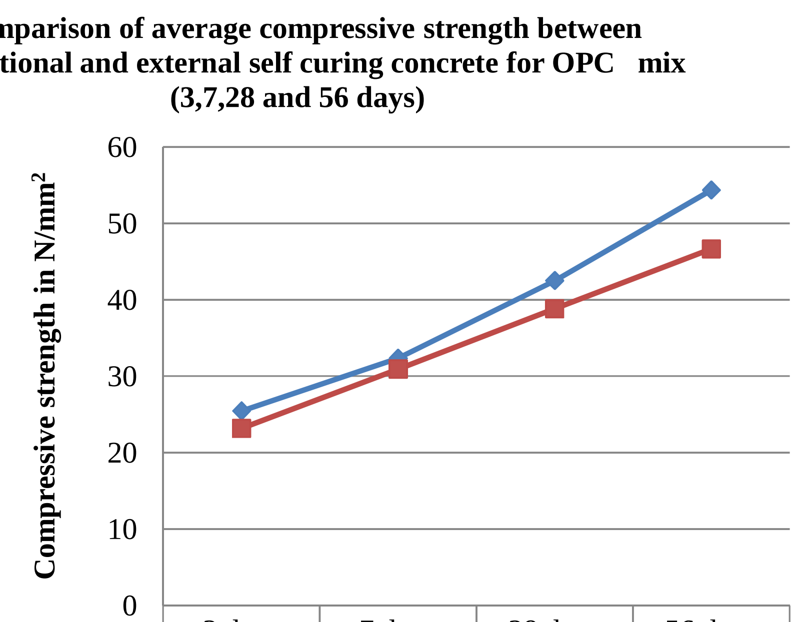


Figure4.5 Compressive strength of external self cured concrete for OPC mix

4.4.1.2 Comparison of Concrete Compressive strength for OPC mix

For 3, 7, 28 and 56 days compressive strength test for OPC concrete mix **.**The results of compressive strength for both conventional and external self curing concrete are shown below. It was observed that the decrease of concrete strength for external self curing concrete is about 9.83% for 3 days as compared to conventional curing concrete, for 7 days the decrease of compressive strength for external self curing concrete is about 4.58% as compared to conventional curing concrete, for 28 days the decrease of compressive strength for external self curing concrete is about 9.44% as compared to conventional curing concrete and then for 56 days the decrease of compressive strength for external self curing concrete is about 16.50% as compared to conventional curing concrete.



	3 days	7 days	28 days	56 days
Compressive strength for conventional curing concrete (N/mm2)	25.47	32.37	42.52	54.36
Compressive strength for external self curing concrete (N/mm2)	23.19	30.95	38.85	46.66

Figure4.6 Comparison of conventional and external self cured concrete for OPC mix

4.4.1.3 Compressive strength of concrete for PPC mix

The tests were performed by placing concrete specimen in Compression Testing Machine. The average of three specimens was tested, computed and the results were tabulated below for 3, 7, 28 and 56 days.

i) Results of Compressive strength test for conventionally cured concrete

Table4.5 Average compressive strength of conventional cured concrete for PPC mix

SI.No	**Weight of the cubes (kg)**	**Failure Load (KN)**	**Compressive strength (N/mm^2)**	**Average Compressive Strength (N/mm^2)**	**Days**
1.	8.492	440	19.56	19.85	3 days
	8.460	460	20.44		
	8.148	440	19.56		
2.	8.274	640	28.44	29.19	7days
	8.446	620	27.56		
	8.412	710	31.56		
3.	8.372	950	42.22	40.59	28days
	8.358	910	40.44		
	8.430	880	39.11		
4.	8.500	1350	60.00	59.25	56days
	8.228	1350	60.00		
	8.406	1300	57.75		

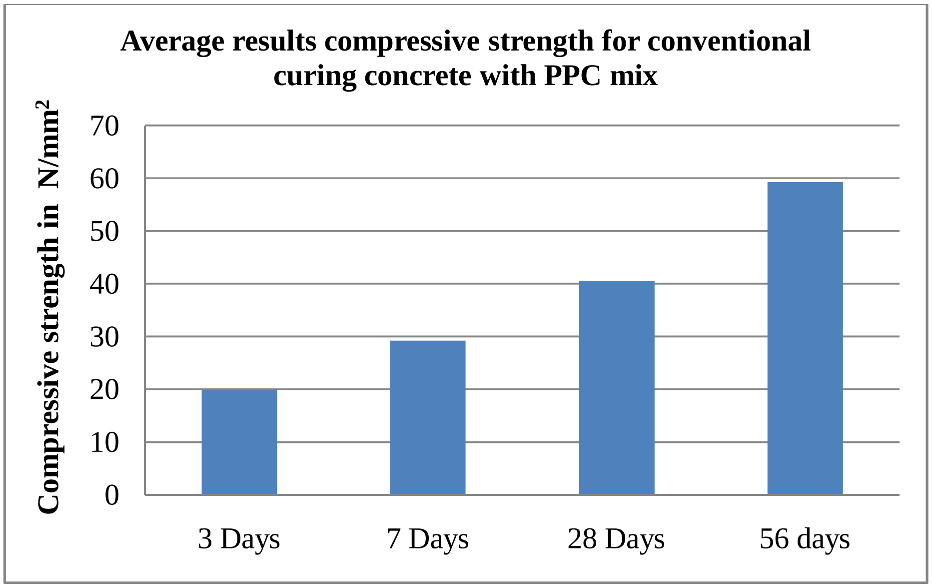


Figure4.7 Compressive strength for conventional cured concrete for PPC mix

ii) Results of Compressive strength test for external self cured concrete

Table4.6 Average compressive strength of external self cured concrete for PPC mix

SI.No	Weight of the cubes (kg)	Failure Load (kN)	Compressive strength (N/mm^2)	Average compressive strength(N/mm^2)	Days
1.	8.332	410	18.22	19.70	3 days
	8.174	520	23.11		
	8.264	400	17.78		
2.	8.392	560	24.88	28.44	7days
	8.342	660	29.33		
	8.302	700	31.11		
3.	8.214	850	37.78	38.37	28 days
	8.390	880	39.11		
	8.262	860	38.22		
4.	8.498	1150	51.11	48.88	56 days
	8.236	1100	48.88		
	8.374	1050	46.66		

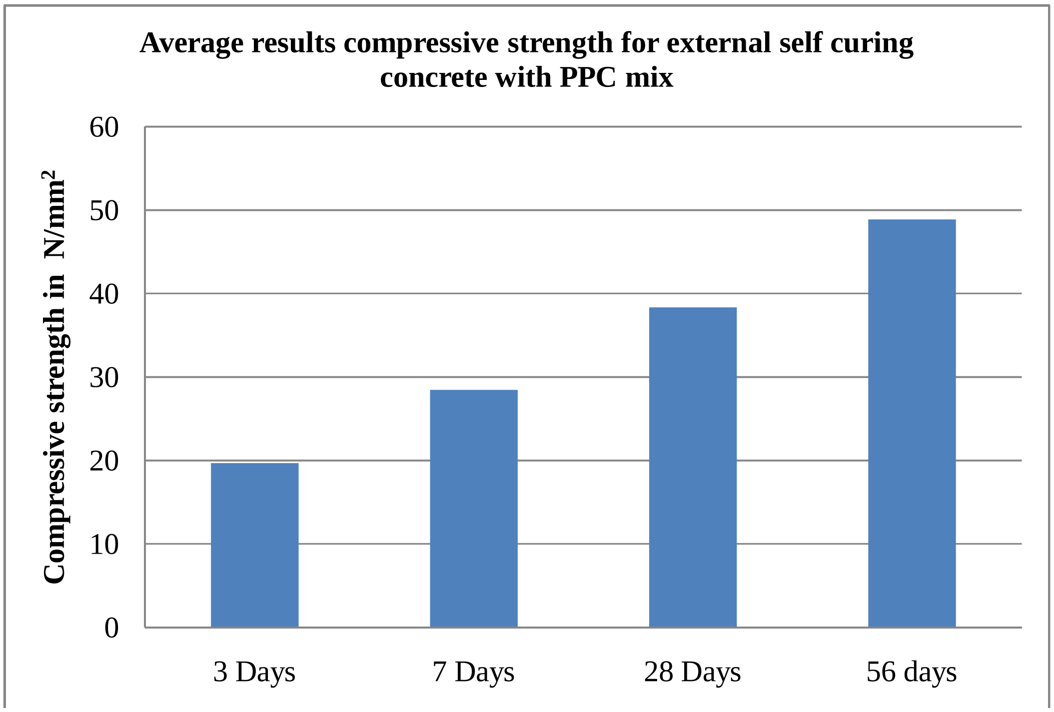
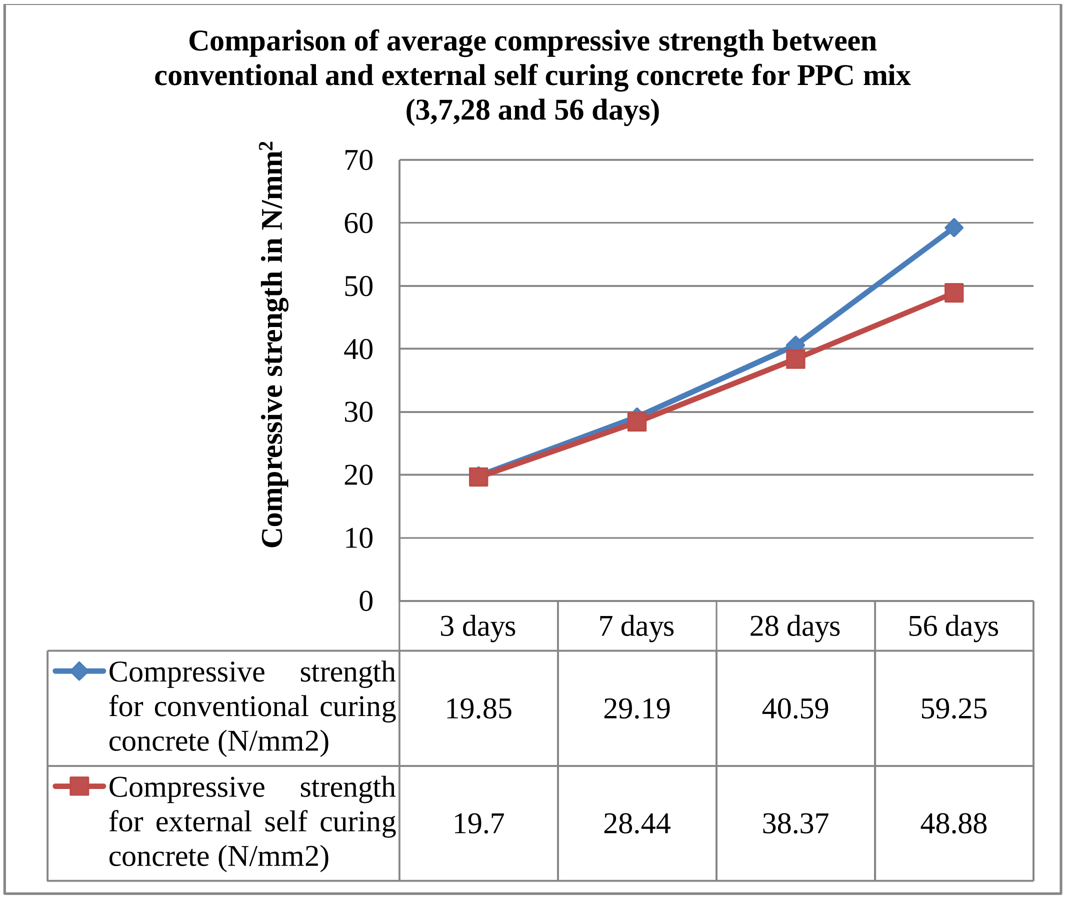


Figure4.8 Compressive strength of external self cured concrete for PPC mix

4.4.1.4 Comparison of concrete compressive strength for PPC mix

For 3, 7, 28 and 56 days compressive strength of PPC concrete mix. The results of compressive strength for both conventional and external self curing concrete are shown below. It was observed that the decrease of concrete strength for external self curing concrete is about 0.76% for 3 days as compared to conventional curing concrete, for 7 days the decrease of compressive strength for external self curing concrete is about 2.63% as compared to conventional curing concrete, for 28 days the decrease of compressive strength for external self curing concrete is about 5.78% as compared to conventional curing concrete and then for 56 days the decrease of concrete strength for external self curing concrete is about 21.21% as compared to conventional curing concrete.



	3 days	7 days	28 days	56 days
Compressive strength for conventional curing concrete (N/mm2)	19.85	29.19	40.59	59.25
Compressive strength for external self curing concrete (N/mm2)	19.7	28.44	38.37	48.88

Figure4.9 Comparison of Compressive strength for PPC mix

4.4.1.5 Comparison of concrete compressive strength for OPC and PPC mixes

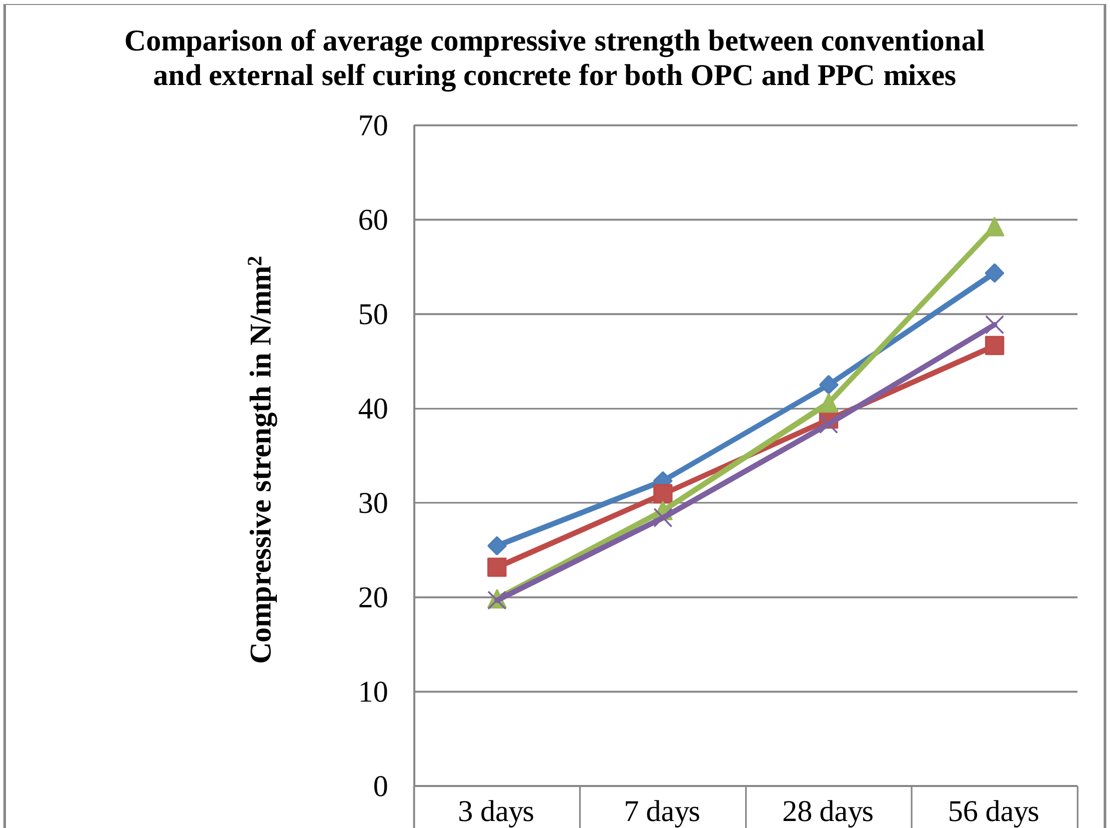
For 3, 7, 28 and 56 days compressive strength for both OPC and PPC concrete mixes**.** The results of compressive strength for both OPC and PPC concrete specimens by conventional and external self curing are described and shown below.

The results showed that the increase of concrete compressive strength for conventional curing concrete is about 28.31% for OPC concrete mix as compared to conventional curing concrete for PPC concrete mix for 3 days, and then the increase of concrete compressive strength for external self curing concrete is about 17.71% for OPC concrete mix as compared to external self curing concrete for PPC concrete mix for 3 days.

For 7 days, it was observed that the increase of concrete strength for conventional curing concrete is about 10.79% for OPC concrete mix as compared to conventional curing concrete for PPC concrete mix, and then the increase of concrete compressive strength for external self curing concrete is about 8.82% for OPC concrete mix as compared to external self curing concrete for PPC concrete mix.

For 28 days, it was observed that the strength of concrete for conventional curing concrete was increased up to 4.75% for OPC concrete mix as compared to conventional curing concrete for PPC concrete mix, and then compressive strength of concrete for external self curing concrete was increased up to 1.25% for OPC concrete mix as compared to external self curing concrete for of PPC concrete mix.

For 56 days, it was also observed that the strength of concrete for conventional curing concrete was increased up to 8.99% for PPC concrete mix as compared to conventional curing concrete for OPC concrete mix, and then compressive strength of concrete for external self curing concrete was increased up to 4.75% for PPC concrete mix as compared to external self curing concrete for OPC concrete mix.



	3 days	7 days	28 days	56 days
Compressive strength by conventional curing for OPC mix (N/mm2)	25.47	32.34	42.52	54.36
Compressive strength by external self curing concrete for OPC mix (N/mm2)	23.19	30.95	38.85	46.66
Compressive strength by conventional curing for PPC mix (N/mm2)	19.85	29.19	40.59	59.25
Compressive strength by external self curing for PPC mix (N/mm2)	19.7	28.44	38.37	48.88

Figure4.10 Comparison of concrete compressive strength for OPC and PPC mixes

4.5 SPLIT TENSILE STRENGTH TEST RESULTS FOR CONCRETE

Split tensile strength test was done to know the tensile strength of concrete. The test was carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and load was applied until the failure of the cylinder along the vertical diameter as described in chapter three. Split tensile strength test was performed on OPC and PPC concrete specimens for both conventional and external self curing concrete for 28 days and the results obtained are described below. The average of three cylindrical specimens of size 150mm diameter and 300mm height was taken and the results were tabulated and interpreted in this section. The total number of twelve cylinders for both OPC and PPC concrete specimens were used.

4.5.1 Result of Split tensile strength test for normal and external self curing concrete for OPC and PPC mixes

The results of 28 days in split tensile strength of concrete for both OPC and PPC concrete mixes specimens by normal curing (when placing specimens into water tank) and external self curing concrete (by the application of curing compound named concure WB on the surface of concrete specimens) were determined and calculated. The results in split tensile strength for conventional and external self curing concrete were obtained using three cylindrical specimens and average value was determined as given below.

4.5.1.1 Split tensile strength of concrete for OPC mix

The tests were performed by placing concrete specimen in Compression Testing Machine. Three specimens were tested, the mean value was computed and the results were given below for 28 days.

i) Results of Split tensile strength test for conventionally cured concrete

Table4.7 Average Split tensile strength of conventionally cured concrete for OPC mix

SI.No	Weight of the cylinders (kg)	Failure Load (KN)	Split tensile strength (N/mm^2)	Average Split tensile strength (N/mm^2)	Days
1.	13.010	250	3.54	3.60	28 days
2	12.954	260	3.68		
3	13.015	255	3.60		

ii) Results of Split tensile strength test for external self cured concrete

Table4.8 Average Split tensile strength of external self cured concrete for OPC mix

SI.No	Weight of the cylinders (kg)	Failure Load (KN)	Split tensile strength (N/mm^2)	Average Split tensile strength (N/mm^2)	Days
1.	12.564	250	3.54	3.44	28 days
2	12.608	220	3.11		
3	12.910	260	3.68		

4.5.1.2 Comparison of concrete split tensile strength for OPC mix

For 28 days split tensile strength of concrete for OPC mix **.**The results of split tensile strength for both conventional and external self curing concrete are shown below. It was observed that the strength of concrete for external self curing concrete was decreased up to 4.65% as compared to conventional curing concrete.

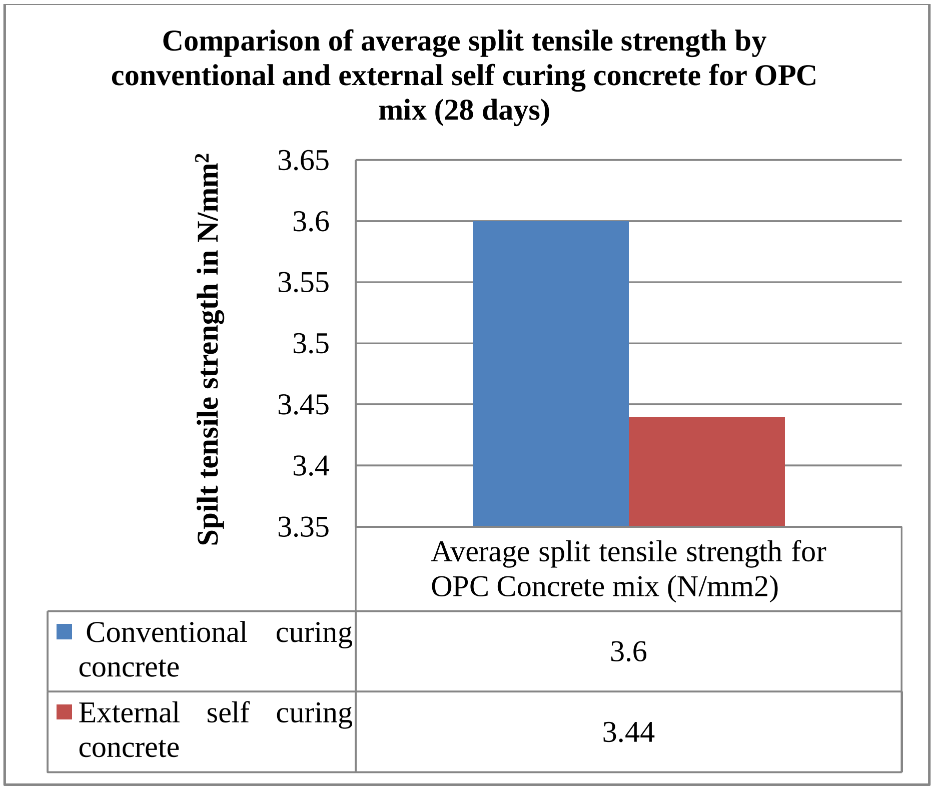


Figure4.11 Comparison of concrete split tensilestrengthfor OPC mix

4.5.1.3 Split tensile strength of concrete for PPC mix

The concrete specimens were placed in Compression Testing Machine. The average of three specimens was tested, the mean value was computed and the results were tabulated below for 28 days.

i) Results of Split tensile strength test for conventionally cured concrete

Table4.9 Average Split tensile strength of conventional cured concrete for PPC mix

SI.No	Weight of the cylinders (kg)	Failure Load (kN)	Split tensile strength (N/mm^2)	Average Split tensile strength (N/mm^2)	Days
1.	12.740	250	3.53	3.48	28 days
2	12.990	240	3.39		
3	12.782	250	3.53		

ii) Results of Split tensile strength test for external self cured concrete

Table4.10 Average Split tensile strength for external self cured concrete for PPC mix

SI.No	Weight of the cylinders (kg)	Failure Load (kN)	Split tensile strength (N/mm^2)	Average Split tensile strength (N/mm^2)	Days
1.	12.672	250	3.53	3.25	28 days
2	12.740	240	3.39		
3	12.636	200	2.83		

4.5.1.4 Comparison of split tensile strength for PPC mix

For 28 days split tensile strength of concrete for PPC concrete mix.The results of split tensile strength for both conventional and external self curing concrete are shown below. It was observed that the strength of concrete for external self curing concrete was decreased up to7.07% as compared to conventional curing concrete.

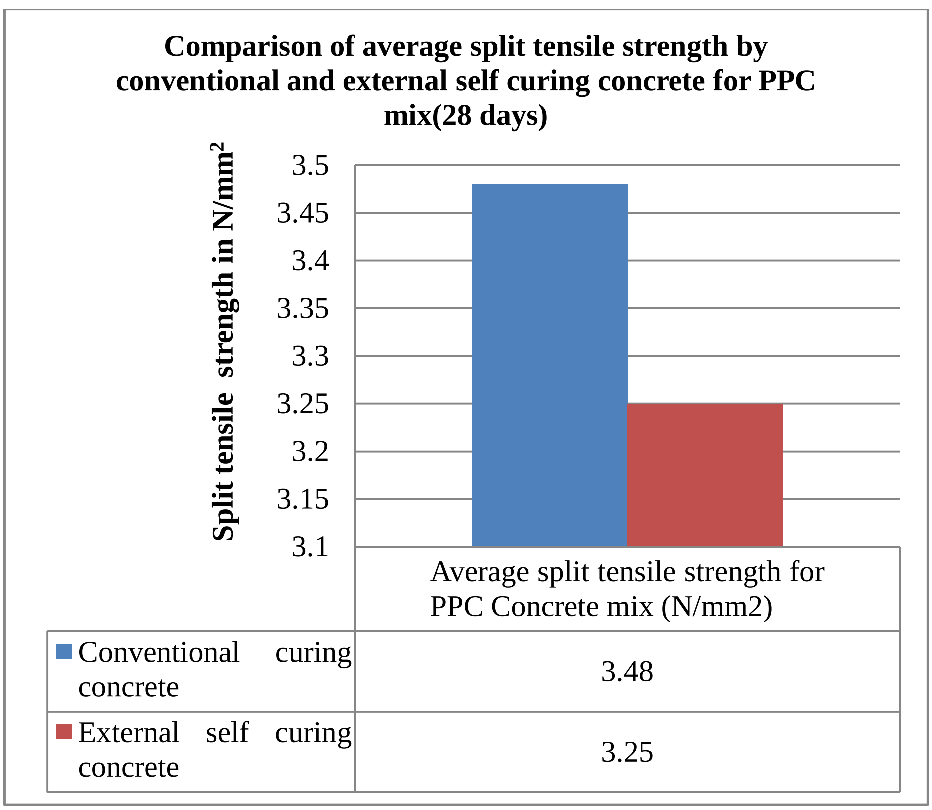
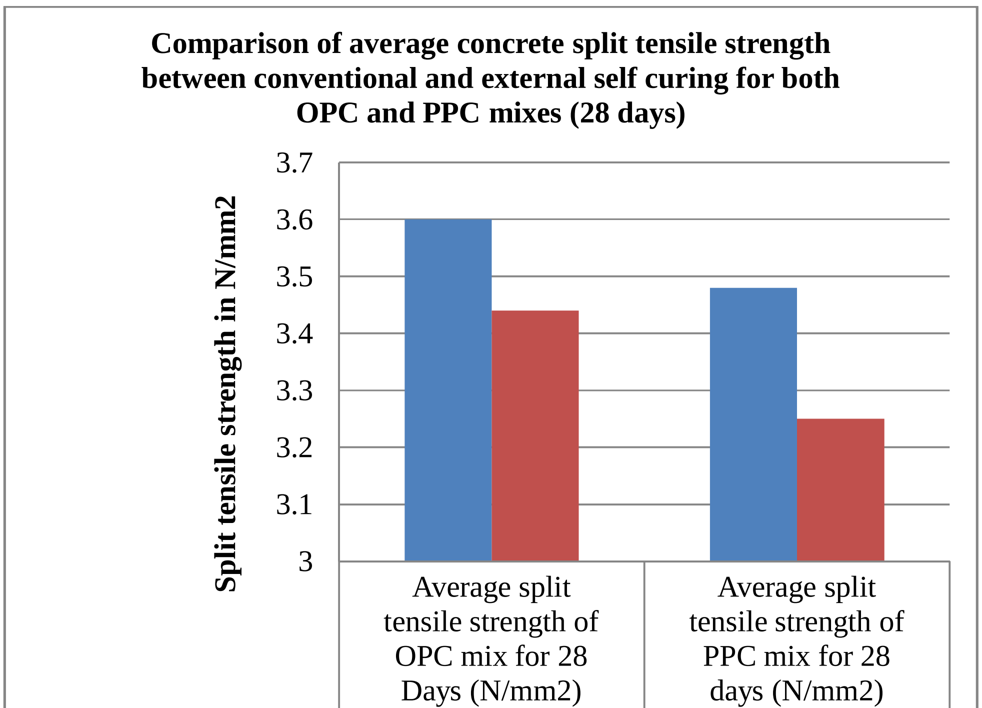


Figure4.12 Comparison of concrete Split tensilestrengthfor PPC mix at 28 days

4.5.5.5 Comparison of split tensile strength for both OPC and PPC concrete mixes

For 28 days split tensile strength of concrete for both OPC and PPC mixes. The results of split tensile strength of both OPC and PPC concrete specimens by conventional and external self curing concrete are described and shown below.

It was observed that the split tensile strength of concrete for conventional curing concrete was increased up to 3.44% for OPC concrete mix as compared to conventional curing concrete for PPC concrete mix, and then the increase of concrete split tensilestrength for external self curing concrete is about 5.84% for OPC concrete mix as compared to external self curing concrete for PPC concrete mix for 28 days.



	Average split tensile strength of OPC mix for 28 Days (N/mm2)	Average split tensile strength of PPC mix for 28 days (N/mm2)
Conventional curing concrete	3.6	3.48
External self curing concrete	3.44	3.25

Figure4.13 Comparison of split tensile strength of concrete for PPC and PPC mixes

4.6 FLEXURAL STRENGTH TEST RESULTS FOR CONCRETE

Flexural strength of concrete is defined as the ability to resist deformation under load. Flexural strength of concrete is a measure of an unreinforced concrete beams or slabs to resist failure in bending.

It was determined for both OPC and PPC concrete mixes specimens by conventional and external self curing concrete for 28 days. Testing to determine flexural strength of all specimens was carried out as per IS: 516-1959 and the procedure of testing is explained in chapter three. Three beam specimens of size 100 × 100 × 500 mm were cast, cured for 28 days and tested in order to determine the average results of flexural strength for both OPC and PPC concrete specimens, the results obtained are presented and discussed below. The total number of twelve beam specimens for both OPC and PPC mixes were used.

4.6.1Results of flexural strength test between normal curing and external self curing concrete for OPC and PPC mixes

The results of 28 days in flexural strength of concrete for both OPC and PPC concrete mixes specimens by normal curing and external self curing concrete (using water curing and concure WB curing compound) were determined by testing three beam specimens to obtain the average value of flexural strength of concrete. The results in flexural strength for conventional and external self curing concrete are given and presented below.

4.6.1.1 Flexural strength of concrete for OPC mix

This test method covers the determination of the flexural strength of concrete by the use of a simple beam with third-point loading. A simply supported concrete prism is loaded by two point loads placed at third points along the span. The load is increased until flexural failure occurs. Based on the peak load, the peak flexural stress within the prism was calculated, the method is commonly referred to as the modulus of rupture.

i) Results of flexural strength test for conventionally cured concrete

Table4.11 Average flexural strength of conventionally cured concrete for OPC mix

SI.No	Weight of the cylinders (kg)	Failure distance "a" (in mm)	Failure Load (KN)	Flexural strength (N/mm^2)	Average flexural strength (N/mm^2)	Days
1.	12.770	127	17.5	6.66	6.62	28 days
2	12.458	136	17	6.80		
3	12.976	155	16	6.40		

ii) Results of flexural strength test for external cured concrete

Table4.12 Average flexural strength of external self cured concrete for OPC mix

SI.No	Weight of the cylinders (kg)	Failure distance "a" (in mm)	Failure Load (KN)	Flexural strength (N/mm^2)	Average flexural strength (N/mm^2)	Days
1.	12.356	180	14.5	5.80	5.60	28 days
2.	12.538	175	14	5.60		
3.	12.460	145	13.5	5.40		

4.6.1.2 Comparison of concrete flexural strength for OPC mix

For 28 days flexural strength of concrete for OPC mix **.**The results of flexural strength for OPC concrete mix for both conventional and external self curing concrete are shown below. It was observed that the decrease inflexural strength of concrete for external self curing concrete is about 18.21% as compared to conventional curing concrete.

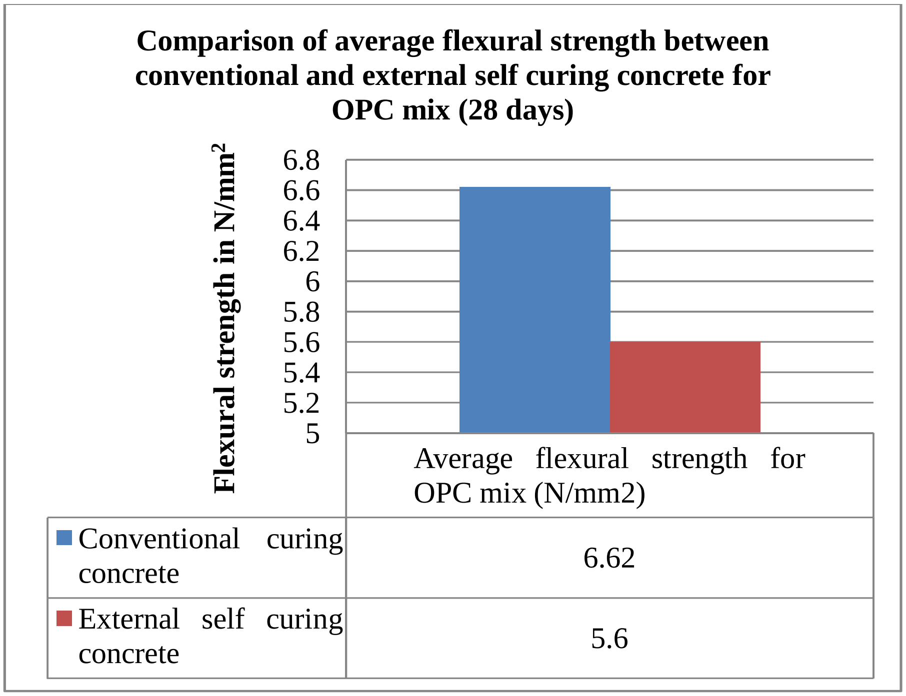


Figure4.14 Comparison of average flexural strength of concrete for OPC mix

4.6.1.3 Flexural strength of concrete for PPC mix

This test covers the determination of the flexural strength of concrete by the use of a simple beam with third-point loading. A simply supported concrete prism is loaded by two point loads placed at third points along the span. The load is increased until flexural failure occurs. Based on the peak load, the peak flexural stress within the prism was calculated and this method is commonly referred to as the modulus of rupture.

iii) Results of flexural strength test for conventionally cured concrete

Table4.13 Average flexural strength of conventionally cured concrete for PPC mix

SI.No	Weight of the cylinders (kg)	Failure distance "a" (in mm)	Failure Load (KN)	Flexural strength (N/mm^2)	Average flexural strength (N/mm^2)	Days
1.	12.326	165	13.5	5.40	5.80	28 days
2	12.884	140	15	6.00		
3	12.250	180	15	6.00		

iv) Results of flexural strength test for external cured concrete

Table4.14 Average flexural strength of external self cured concrete for PPC mix

SI.No	Weight of the cylinders (kg)	Failure distance “a” (in mm)	Failure Load (KN)	Flexural strength (N/mm^2)	Average flexural strength (N/mm^2)	Days
1.	12.198	160	12	4.80	4.47	28 days
2	12.656	185	10	4.00		
3	12.256	175	11.5	4.60		

4.6.1.4 Comparison of concrete flexural strength for PPC mix

For 28 days flexural strength of concrete for PPC concrete mix **.**The results of flexural strength for PPC concrete mix for both conventional and external self curing concrete are described below. It was observed that the decrease in flexural strength of concrete for external self curing concrete is about 29.75% as compared to conventional curing concrete.

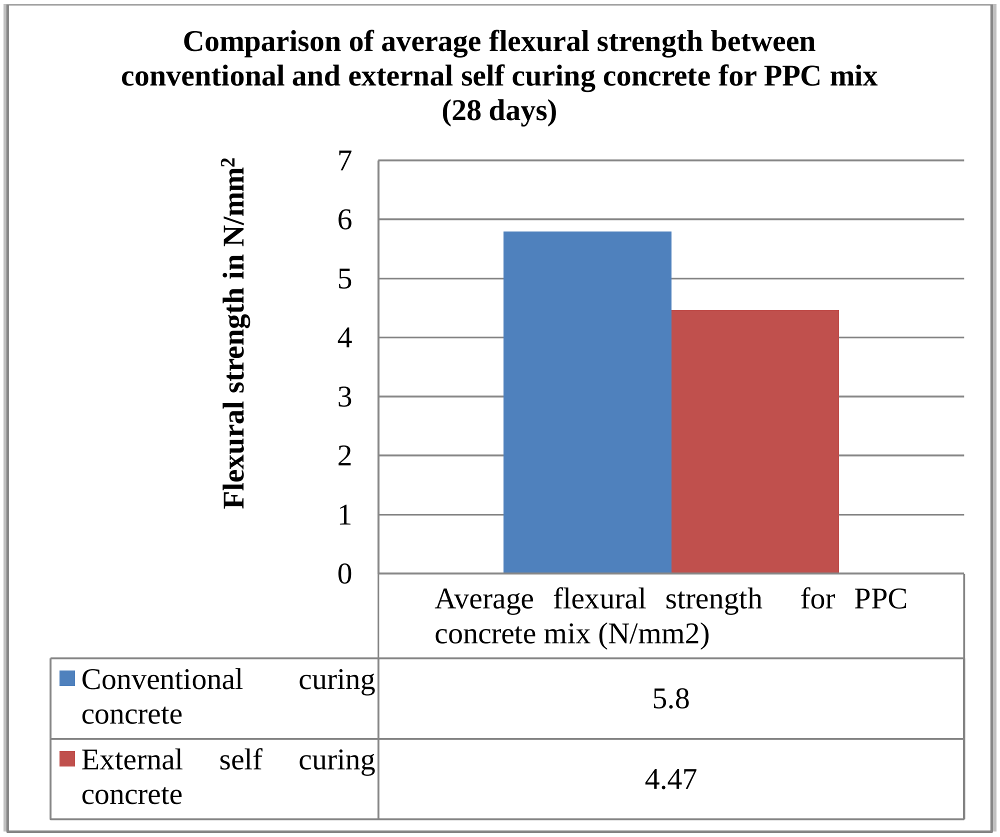


Figure4.15 Comparison of average flexural strength of concrete for PPC mix

4.6.1.5 Comparison of concrete flexural strength for both OPC and PPC mixes

For 28 days flexural strength of concrete for both OPC and PPC concrete mixes specimens**.** The results of flexural strength for OPC and PPC concrete specimens by conventional and external self curing concrete are described and presented below.

It was observed that the increase of concrete flexural strength for conventional curing concrete is about14.13% for OPC concrete mix as compared to conventional curing concrete for PPC concrete mix, and then the increase of concrete flexural strength for external self curing concrete is about 25.27% for OPC concrete mix as compared to external self curing concrete for PPC concrete mix for 28 days.

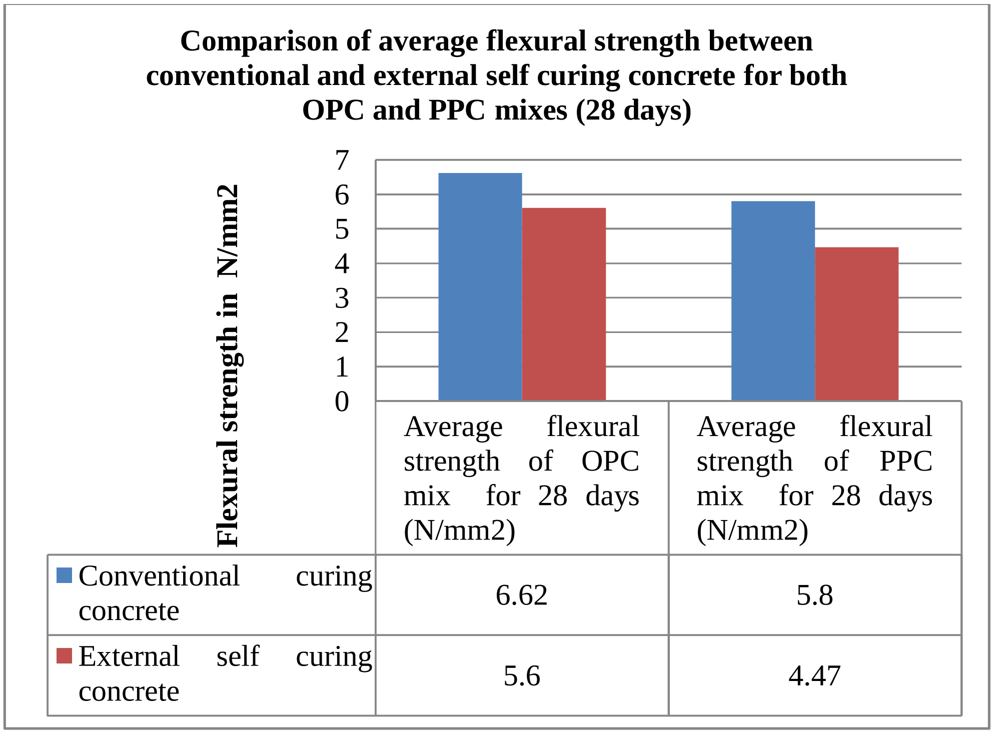


Figure4.16 Comparison of flexural strength of concrete for OPC and PPC mixes

4.6.1.6 Results of Scanning Electron Microscopy (SEM) for OPC and PPC concrete mixes

In the present study, the microstructure of the concrete was analysed using Scanning Electron Microscope (SEM) which practically helps to visualize the microstructure of the hydrated cement paste.SEM was carried out for both OPC and PPC concrete mixes to obtain high magnification images and chemical compositions (EDSorEnergy Dispersive Spectroscopy) of concrete from both concrete mixesand the results are shown in the figures below.

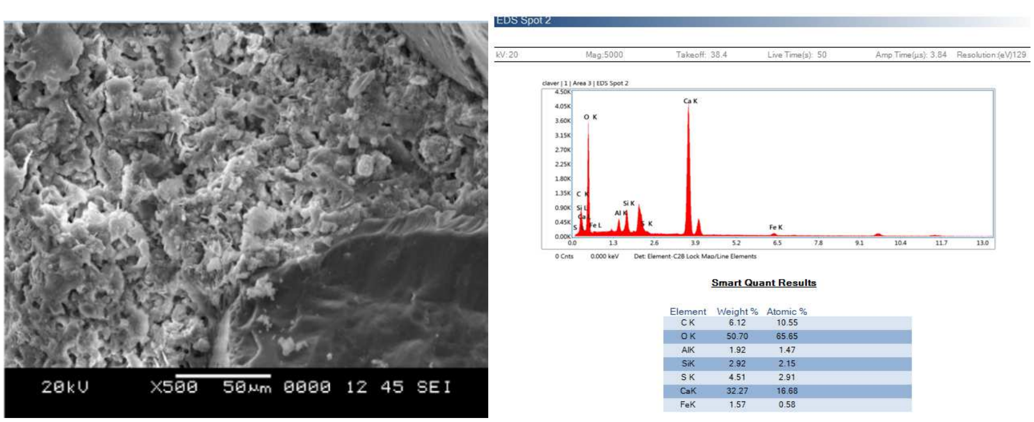
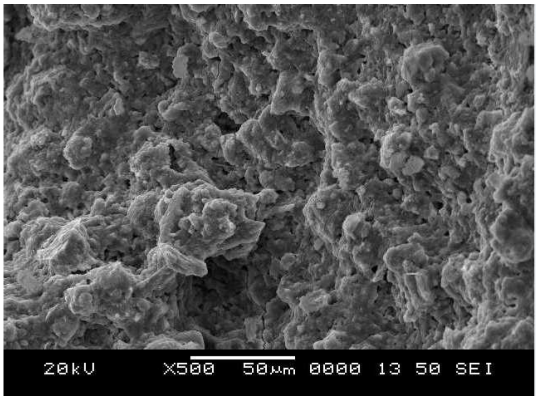
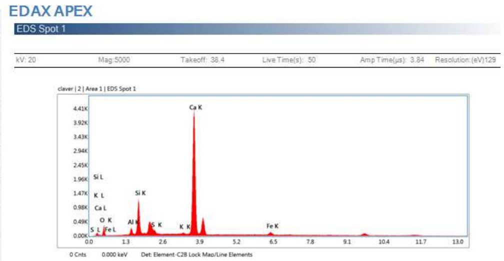


Figure4.17 SEM images and EDSspectra of conventional curing concrete for OPC mix

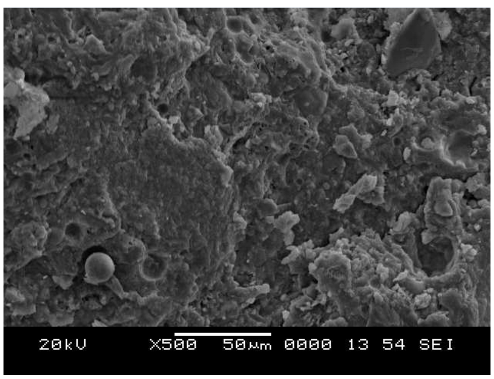


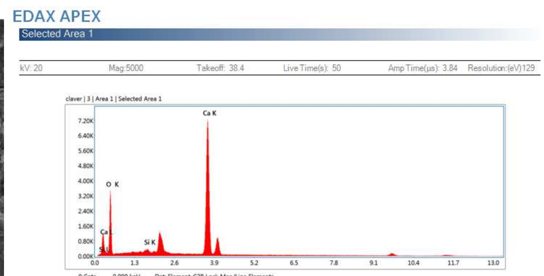


Smart Quant Results

Element	Weight %	Atomic %
O K	15.21	29.86
AlK	1.86	2.17
SiK	8.38	9.38
S K	5.15	5.04
K K	0.56	0.45
CaK	64.91	50.89
FeK	3.93	2.21

Figure4.18 SEM images and EDSspectra of external self curing concrete for OPC mix

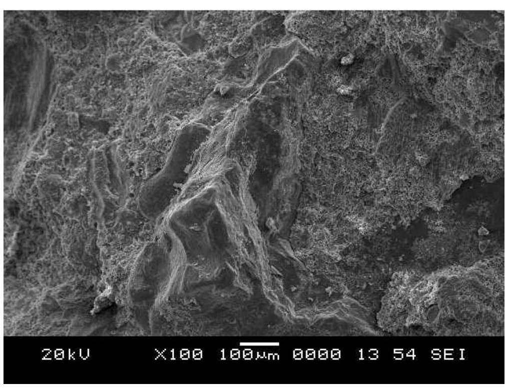


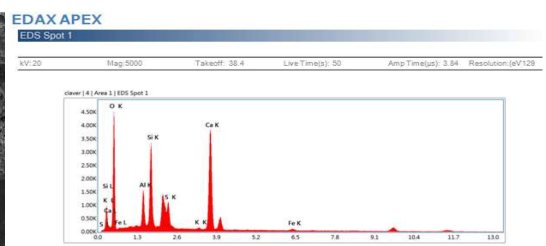


Smart Quant Results

Element	Weight %	Atomic %
O K	51.22	72.26
SiK	1.12	0.90
CaK	47.66	26.84

Figure4.19 SEM images and EDS spectra of conventional curing concrete for PPC mix





Smart Quant Results

Element	Weight %	Atomic %
O K	48.69	67.06
AlK	5.02	4.10
SiK	9.98	7.83
S K	9.02	6.20
K K	0.29	0.16
CaK	25.70	14.13
FeK	1.30	0.51

Figure4.20 SEM images and EDS spectra of external self curing concrete for PPC mix

4.7 CONCRETE WATER ABSORPTION TEST RESULTS

Concrete water absorption is the ability of concrete to retain a certain amount of liquid (water) in their air spaces, which is a key property when it comes to the resistance of the concrete in the environment. Concrete water absorption is determined by measuring the increase in mass as a percentage of dry mass. It was determined for both OPC and PPC concrete specimens by conventional and external self curing concrete after 28 days. Testing to determine concrete water absorption of all specimens was carried out as per ASTM C642 and the procedures of testing were explained in chapter three.

The cubes specimens of size 150 mm × 150 mm × 150 mm were cast, cured for 28 days and then tested in order to determine concrete water absorption between normal and external self curing concrete for both OPC and PPC concrete specimens.

Average of three specimens was taken and the results are tabulated and interpreted in this section. The total number of twenty four cubes for both OPC and PPC concrete specimens were used.

4.7.1 Results of concrete water absorption for normal and external self curing concrete for OPC and PPC mixes

The specimens from OPC and PPC concrete mixes were cast, then cured for conventional curing and external self curing concrete for 28days. Concrete water absorption was tested after 28 days of curing period. The oven-dry mass of each specimen was obtained and noted as the dry weight W1 of the specimen. The saturated mass (using immersion of cube specimens in water) of samples was determined and noted as the wet weight W2 of the specimen. Finally, the saturated mass by using immersion and boiling in water was obtained and the weight was noted as weight W3 of the specimen. The condition and the procedures for concrete water absorption test were considered and described careful step by step as shown clearly in this section as per ASTM C642.

The results for percentage concrete water absorption were determined for average weight of three specimens taken into account and the amount of water absorbed under specified conditions was determined by the following formulas shown below.

- Concrete water absorption after immersion,% $=[(W2- W1)/ W1] \times 100$ and

- Concrete water absorption after immersion and boiling,% =[(W3-W1)/W1] ×100

Where: W 1: Mass of oven-dried sample (in gm), W 2: Mass of surface-dry sample in air after immersion (in gm), W 3: Mass of surface-dry sample in air after immersion and boiling.

4.7.1.1 Concrete water absorption for OPC mix

Concrete water absorption was tested after 28 days of curing period for both conventional and external self curing concrete and the results are clearly described and presented as shown below.

i) Concrete water absorption for normal curing concrete for OPC mix

Table4.15 Concrete water absorption of normal curing concrete for OPC mix

Different environmental conditions for specimens samples	**Weight of sample specimens in different environmental conditions (in grams)**			**Time intervals for specimen samples**
	SI.No	**Weight of samples (cubes in kg)**	**Average weight (kg)**	
Oven-dry mass of each specimen (dry weight of the specimen for 12 hours),W1	1.	8.294	8.364	24 hours
	2.	8.472		
	3.	8.326		
Saturated mass (using immersion) of samples in water(wet weight of the specimen for 48 hours),W2	1.	8.408	8.468	48 hours
	2.	8.576		
	3.	8.422		
Saturated mass by using immersion in boiling water(specimen kept in hot water for 5 hours),W 3	1.	8.420	8.474	5 hours
	2.	8.580		
	3.	8.424		

Two different values of the concrete samples' capability of water absorption was calculated as follows:

- Concrete water absorption after immersion, % = $[(W2- W1)/ W\mathbf{1}] \times 100$

  $\Rightarrow [(8.468- 8.364)/ 8.364] \times 100 =$ **1.24 %**
- Concrete water absorption after immersion and boiling ,% $=[(W3-W1)/W1] \times 100$

  $\Rightarrow [(8.474- 8.364)/ 8.364] \times 100 =$ **1.31 %**

Where: W1: mass of oven-dried sample (in gm), W2: mass of surface-dry sample in air after immersion (in gm), W3: mass of surface-dry sample in air after immersion and boiling (in gm).

ii) Concrete water absorption for external self curing concrete for OPC mix

Table4.16 Concrete water absorption of external self curing concrete for OPC mix

Different environmental conditions for specimens samples	**Weight of sample specimens in different environmental conditions (in grams)**			**Time intervals for specimen samples**
	SI.No	**Weight of samples (cubes in kg)**	**Average weight (kg)**	
Oven-dry mass of each specimen (dry weight of the specimen for 12 hours),W1	1.	8.286	8.229	24 hours
	2.	8.040		
	3.	8.362		
Saturated mass (using immersion) of samples in water(wet weight of the specimen for 48 hours), W2	1.	8.412	8.382	48 hours
	2.	8.216		
	3.	8.518		
Saturated mass by using immersion in boiling water(specimen kept in hot water for 5 hours),W 3	1.	8.500	8.450	5 hours
	2.	8.270		
	3.	8.580		

Two different values of the concrete samples' capability of water absorption was calculated as follows:

- Concrete water absorption after immersion, % = [(W2- W1)/ W1] $\times$100

  => [(8.382- 8.229)/ 8.229] $\times$ 100= **1.85%**
- Concrete water absorption after immersion and boiling ,%

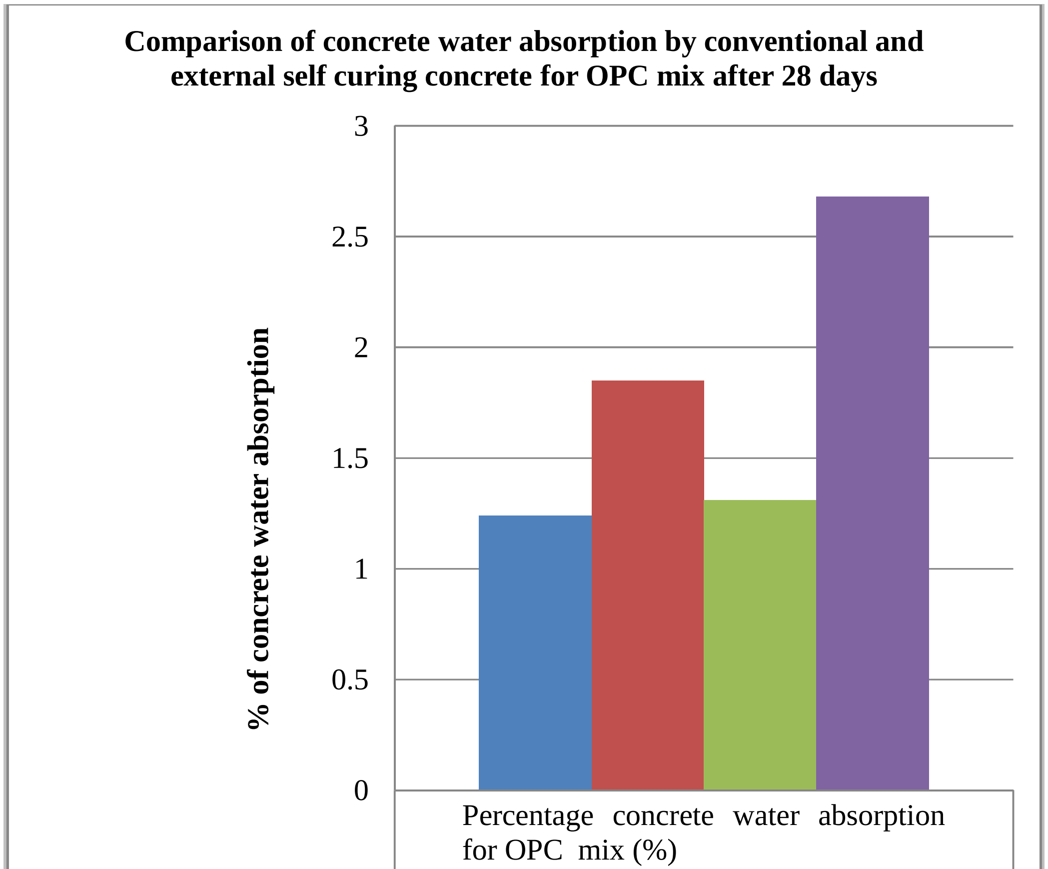
  =[(W3-W1)/ W1] $\times$100

  => [(8.450- 8.229)/ 8.229] $\times$ 100= **2.68%**

Where: W1: mass of oven-dried sample (in gm), W2: mass of surface-dry sample in air after immersion (in gm), W3: mass of surface-dry sample in air after immersion and boiling (in gm).

4.7.1.2 Comparison of concrete water absorption for conventional and external self curing for OPC mix

The results of percentage concrete water absorption after 28 days for OPC concrete mix by both conventional and external self curing concrete are described below. It was observed that percentage of concrete water absorption after immersion, external self curing concrete was increased up to 0.61% as compared to conventional curing concrete. The percentage of concrete water absorption after immersion and boiling was observed that external self curing concrete was increased up to 1.37% as compared to conventional curing concrete after 28 days.



	Percentage concrete water absorption for OPC mix (%)
Conventional curing after immersion	1.24
External self curing after immersion	1.85
Conventional curing after immersion and boiling	1.31
External self curing after immersion and boiling	2.68

Figure4.21 Concrete water absorption of conventional and self curing for OPC mix

4.7.1.3 Concrete water absorption for PPC mix

The test for concrete water absorption was determined after 28 days of curing period for both conventional and external self curing concrete and the results are clearly presented and tabulated as shown below.

i) Concrete water absorption for normal curing concrete for PPC mix

Table4.17 Concrete water absorption for normal curing concrete for PPC mix

Different environmental conditions for specimens samples	**Weight of sample specimens in different environmental conditions (in grams)**			**Time intervals for specimen samples**
	SI.No	**Weight of samples (cubes in kg)**	**Average weight (kg)**	
Oven-dry mass of each specimen (dry weight of the specimen for 12 hours),W1	1.	8.082	8.222	24 hours
	2.	8.266		
	3.	8.320		
Saturated mass (using immersion) of samples in water(wet weight of the specimen for 48 hours), W2	1.	8.196	8.334	48 hours
	2.	8.384		
	3.	8.424		
Saturated mass by using immersion in boiling water(specimen kept in hot water for 5 hours),W3	1.	8.208	8.376	5 hours
	2.	8.492		
	3.	8.428		

Two different values of the concrete samples' capability of water absorption was calculated as follows:

- Concrete water absorption after immersion, % = [(W2- W1)/ W1] ×100

  => [(8.334- 8.222)/ 8.222] ×100 = **1.36%**

- Concrete water absorption after immersion and boiling ,% =[(W3-W1)/W1]×100

  => [(8.376- 8.222)/ 8.222] ×100 = **1.87%**

Where: W1: mass of oven-dried sample (in gm), W2: mass of surface-dry sample in air after immersion (in gm), W3: mass of surface-dry sample in air after immersion and boiling (in gm).

ii) Concrete water absorption for external self curing concrete for PPC mix

Table4.18 Concrete water absorption for external self curing concrete for PPC mix

Different environmental conditions for specimens samples	**Weight of sample specimens in different environmental conditions (in grams)**			**Time intervals for specimen samples**
	SI.No	**Weight of samples (cubes in kg)**	**Average weight (kg)**	
Oven-dry mass of each specimen (dry weight of the specimen for 12 hours),W1	1.	8.138	8.156	24 hours
	2.	8.236		
	3.	8.096		
Saturated mass (using immersion) of samples in water(wet weight of the specimen for 48 hours), W2	1.	8.302	8.315	48 hours
	2.	8.418		
	3.	8.226		
Saturated mass by using immersion in boiling water(specimen kept in hot water for 5 hours),W3	1.	8.390	8.384	5 hours
	2.	8.474		
	3.	8.290		

Two different values of the concrete samples' capability of water absorption was calculated as follows:

- Concrete water absorption after immersion, % = [(W2- W1)/ W1] ×100

  => [(8.315- 8.156)/ 8.156] ×100 = **1.94%**

- Concrete water absorption after immersion and boiling,%

  =[(W3-W1)/ W1] ×100

  = >[(8.384- 8.156)/ 8.156] ×100 = **2.79%**

Where:W1: Mass of oven-dried sample (in gm), W2: Mass of surface-dry sample in air after immersion (in gm), W3: Mass of surface-dry sample in air after immersion and boiling (in gm).

4.7.1.3 Comparison of concrete water absorption for conventional and external self curing within PPC mix.

The results of percentage concrete water absorption after 28 days for PPC concrete mix for both conventional and external self curing concrete are described below. It was observed that percentage of concrete water absorption after immersion, external self curing concrete was increased up to 0.58% as compared to conventional curing concrete. The was percentage of concrete water absorption after immersion and boiling was observed that external self curing concrete was increased up to 0.92% as compared to conventional curing concrete.

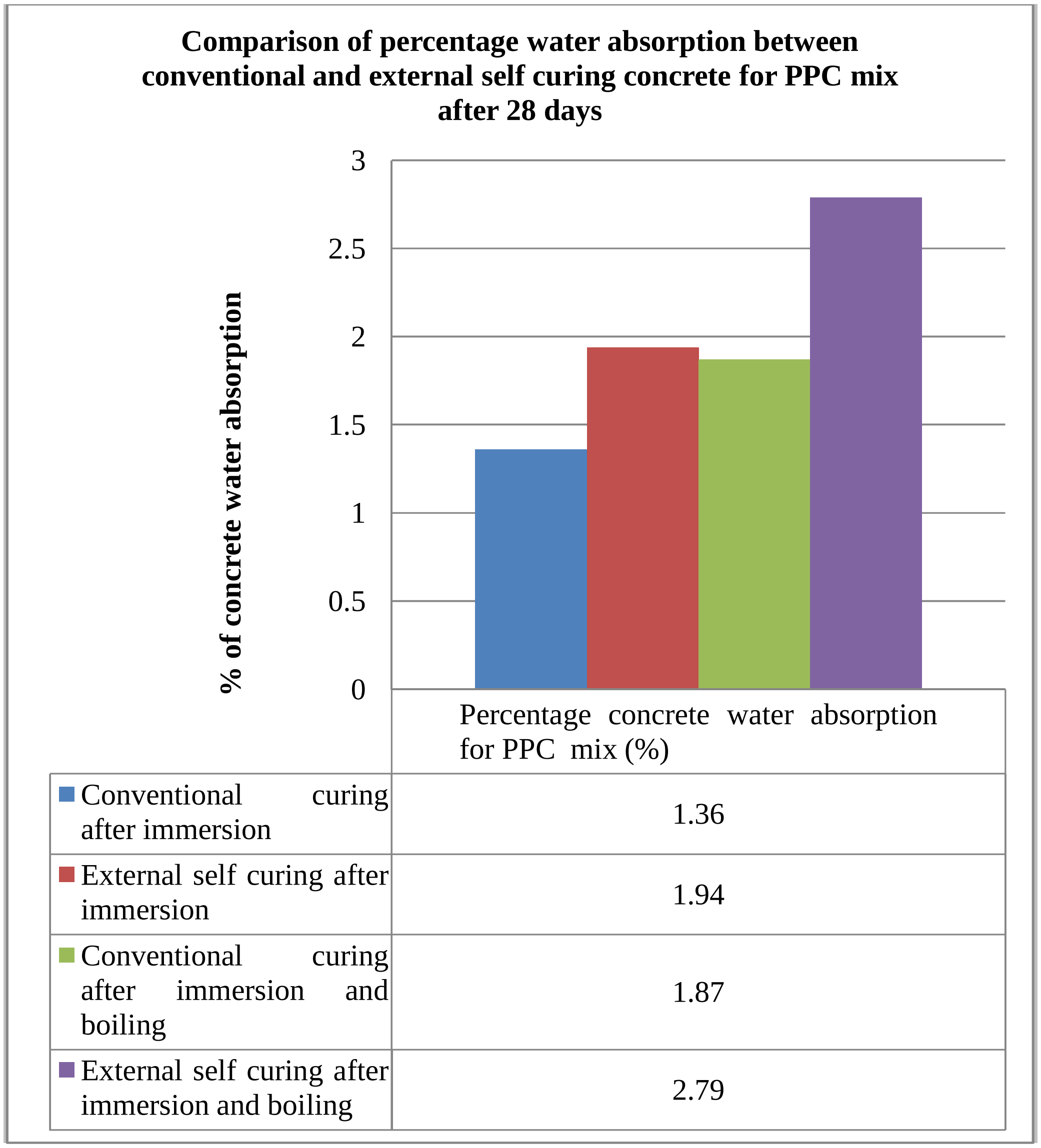


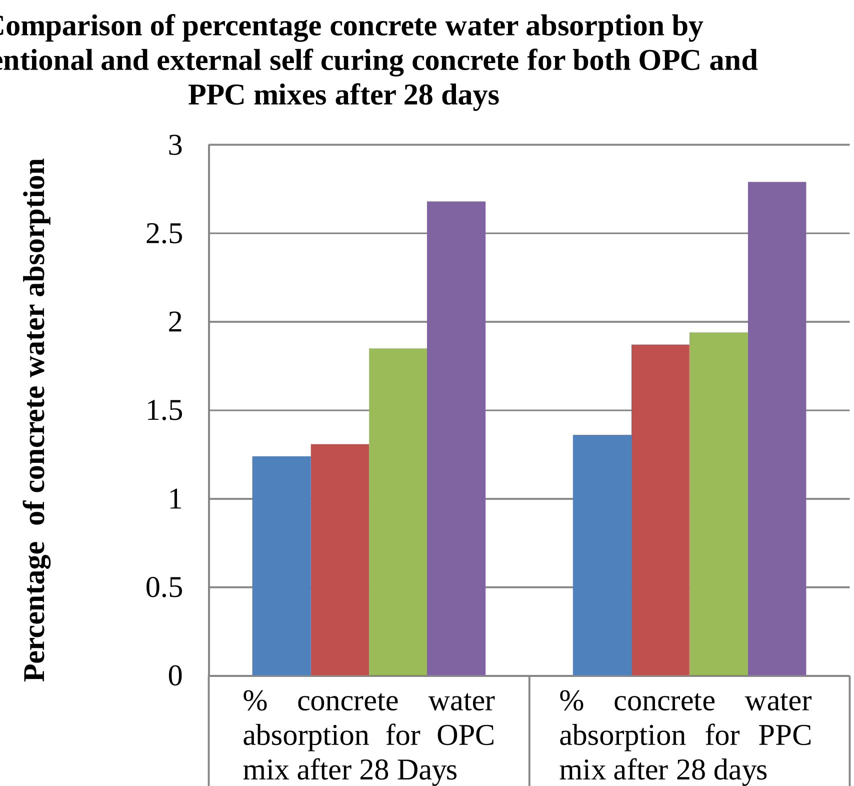
Figure4.22 Concrete water absorption for conventional and self curing for PPC mix.

4.7.1.3 Comparison of concrete water absorption for both OPC and PPC mixes

The results of percentage concrete water absorption for both OPC and PPC concrete specimens by conventional and external self curing concrete are described and presented in details as shown below.

The results show that the percentage of concrete water absorption after immersion, conventional curing concrete was increased up to 0.12% for PPC concrete mix as compared to conventional curing concrete for OPC concrete mix after 28 days, and then percentage of concrete water absorption after immersion and boiling was observed that conventional curing concrete was increased up to 0.56% for PPC concrete mix as compared to conventional curing concrete for OPC concrete mix.

It was observed that percentage of concrete water absorption after immersion, external self curing concrete was increased up to 0.009% for PPC concrete mix as compared to external self curing concrete for OPC concrete mix after 28 days, and then percentage of concrete water absorption after immersion and boiling was observed that external self curing concrete was increased up to 0.29% for PPC concrete mix as compared to external self curing concrete for OPC concrete mix.



	% concrete water absorption for OPC mix after 28 Days	% concrete water absorption for PPC mix after 28 days
Conventional curing after immersion	1.24	1.36
Conventional curing after immersion and boliing	1.31	1.87
External self curing after immersion	1.85	1.94
External self curing after immersion and boiling	2.68	2.79

Figure4.23 Comparison of concrete water absorption for both OPC and PPC mixes

CHAPTER 05

CONCLUSIONS

5.1 GENERAL

As elaborated in the previous chapters, experimental investigation for the comparative study on the strength of external self curing concrete and conventional curing concrete regarding the compressive strength, split tensile strength, flexural strength and concrete water absorption have been done. The test results obtained were analysed and discussed in the previous chapters. Based on the detailed analysis, important conclusions are summarized in this chapter.

5.2 CONCLUSIONS

On the basis of the results obtained from the present study, the following conclusions can be drawn:

- For OPC mix, the compressive strength, split tensile strength and flexural strength of conventional curing concrete are greater than external self curing concrete about 9.44% ,4.65% and 18.21%.

- For PPC concrete mix, the compressive strength, split tensile strength and flexural strength of conventional curing concrete are greater than external self curing concrete about 5.78%, 7.07% and 29.75%.

- The compressive strength between OPC and PPC mixes, for 28 days, conventional curing and external self curing concrete for OPC mix are greater than conventional and external self curing concrete for PPC mix about 4.75% and 1.25%. For 56 days, conventional and external self curing concrete for PPC mix is greater than conventional and external self curing concrete for OPC mix about 8.99% and 4.75%.

- The split tensile and flexural strength between OPC and PPC mixes for 28 days. For split tensile strength, conventional and external self curing concrete for OPC mix are greater than conventional and external self curing concrete for PPC mix about 3.44% and 5.84%. For flexural strength, conventional and external self curing concrete for OPC mix are greater than conventional and external self curing concrete for PPC mix about 14.13% and 25.27%.

- The concrete strengths for both OPC and PPC mix, it was observed that conventional curing concrete for both binding materials has greater results as compared to external self curingconcrete;also the strength of external self curing concrete is good as they are greater than target mean strength designed.

- The percentage of concrete water absorption after immersion and water absorption after immersion and boiling (OPC and PPC mixes). After immersion, conventional and external self curing concrete for PPC mix are greater than conventional and external self curing concrete for OPC mix about 0.12% and0.56%.After immersion and boiling, conventional and external self curing concrete for PPC mix are greater than conventional and external self curing concrete for OPC mix about0.009%and 0.29%.

- External self-curing concrete is the answer to the many problems faced in construction industries due to lack of proper curing, lack of water in certain areas and it is an alternative to conventional curing concrete in desert regions where scarcity of water is a major problem.

- External self-curing concrete is more economical because it eliminates the curing charges and efficiently adapted in remote areas as well as in the areas where there is water scarcity problem. Spray application reduces labor costs, eliminates the need for alternative curing systems. The curing compound increases water retention for self cured concrete. Concrete with curing compound gives smooth and fine finished surface than normal curing concrete.

- External self-curing concrete is the best solution to the problems faced in the desert region and faced due to lack of proper curing, the strength of external self curing concrete is increased by applying the curing compound on concrete surface.Curing compound seals the concrete surface effectively by forming monomolecular film on the surface immediately after placing .The results have been attained in strength with small amount of water, so this method can be implemented in construction field.

5.3 SCOPE FOR FUTURE STUDIES

The present investigation can be extended in the following ways:

- The present study can be continued by using different w/c ratios which helps in gaining concrete strength and also to analyze the effect of w/c ration onthe strength of conventional and external self curing concrete.
- The present study has been studied using ordinary Portland cement(OPC) and Portland pozzolana cement (PPC), so the study can be done using other types of binding materials to investigate the effect of curing compound on concrete strength.
- The present study has been carried out using concure WB curing compound for external self curing concrete, so the study can be done using different types of curing compounds to analyze the best one for concrete strength.
- The study of durability characteristics of conventional and external self curing concrete can be carried out.
- Beside plain concrete, the effect of curing compounds on reinforced concrete can also be studied.
- It should be necessary to check the temperature effect on the surface of self curing concrete and other essential required properties for good quality concrete production.

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